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TASK A

MANUFACTURING CHECKOUT OF

ORBITAL OPERATIONAL STAGES

MIDTERM REPORT

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LOCKHEED MISSILES & SPACE COMPANY

Large Space Vehicle Programs

Sunnyvale, California

Prepared by:

Frank L Day

F. L. Day

Louis L Haas

L. L. Haas

W T Scarborough

W. T. Scarborough

R A Blais

R. A. Blais

Prepared for
Vehicle Systems Checkout Division
Quality and Reliability Assurance Laboratory
George C. Marshall Space Flight Center
National Aeronautics & Space Administration

FOREWORD

This report has been prepared in compliance with requirements of Contract NAS 8-11477, for a midterm report on Task A of the contract. The contract supports a study of the peculiarities of orbital operational Saturn stages and determination of the impact of these peculiarities on post manufacturing checkout. This report presents results of work carried on through 24 February 1965. Premises for the early work precluded consideration of significant equipment changes in evaluating desirable manufacturing checkout procedures, excluded payload participation in orbital checkout, and identified reference stages as S-IVB and IU configured for Saturn V, Series 505-506.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

APPENDIXES

Appendix 1	Bibliography
Appendix 2	Orbital Checkout Parameters for IU-9 (Extracted from IP&C List, IU-9)
Appendix 3	SIVB Switch Selector Output Channel Assignments
Appendix 4	Stage Systems Tests Guidelines

CHAPTER 1

INTRODUCTION AND CONCLUSIONS

1.0 PURPOSE

In the near future propulsive stages for use in lunar and deep space missions will more and more frequently be placed in a parking orbit with their payload prior to commitment to the deep space mission. Checkout of the stage and payload while in this parking orbit, is essential to mission success, and is included in operational planning for such missions. The impact of this new operating situation on the scope of factory checkout activities prior to hardware shipment to the launch site may be significant.

The Quality and Reliability Laboratory at Geroge C. Marshall Space Flight Center recognized the potential significance of this impact and, as part of contract NAS 8-11477, contracted with Lockeed Missiles and Space Company to study stage peculiar situations and identify those areas of classical post manufacturing checkout of stages which require change or addition to accommodate the peculiarities of orbital operational stages. The reference stages designated for the study were Saturn S-IVB and Instrument Unit as planned for Saturn V, Series 505-506 configurations.

2.0 DISCUSSION

The most striking feature of the checkout of an Orbital Operational Stage will occur in the simulated flight test, depicted as the last bubble of figure 1.1. For such a stage the flight profile itself will include some overt provision for checkout of the stage on orbit. In fact, for stages such as the IU (V) and S-IVB, a major element of orbital operations will be orbital checkout.

Thus a major portion of the simulated flight test presented in Figure 1.1 is a simulated orbital checkout, as expanded in Figure 1.2. The prime area of interest is in the expanded area between T4 and T6 on Figure 1.2. The line items in the expansion on Figure 1.2 represent the general kinds of checkout activities (and their sequence) that might be simulated during a post manufacturing checkout.

3.0 SCOPE OF REPORT

This report represents the work performed during the first half of the study authorized by the contract. It contains five chapters and a section containing Appendixes. The first chapter, "Introduction and Conclusions" contains those conclusions which resulted from consideration of the S-IVB and IU stages as a single orbiting system. Chapter 2 contains the study of the post manufacturing checkout requirements for the S-IVB, and Chapter 3 is the study of the IU under similar conditions. Both chapters list the recommendations and conclusions reached by consideration of the individual requirements of these stages. Chapter 4 examines the desirability of the actual mating of these stages for simulation of the orbital checkout condition. The fifth chapter presents a review of the requirements of section 7.10.3 of "Space Vehicle Stage Analysis and Checkout Guidelines" aimed at identifying those requirements applicable to an orbiting system.

4.0 APPROACH

Two parallel courses of attack were pursued in identifying greater detail in the area between T4 and T6 of Figure 1.2. The first course assumes a test configuration as presented in Figure 1.3. This configuration excludes any hardline connections except as required for safety of equipment or test personnel.

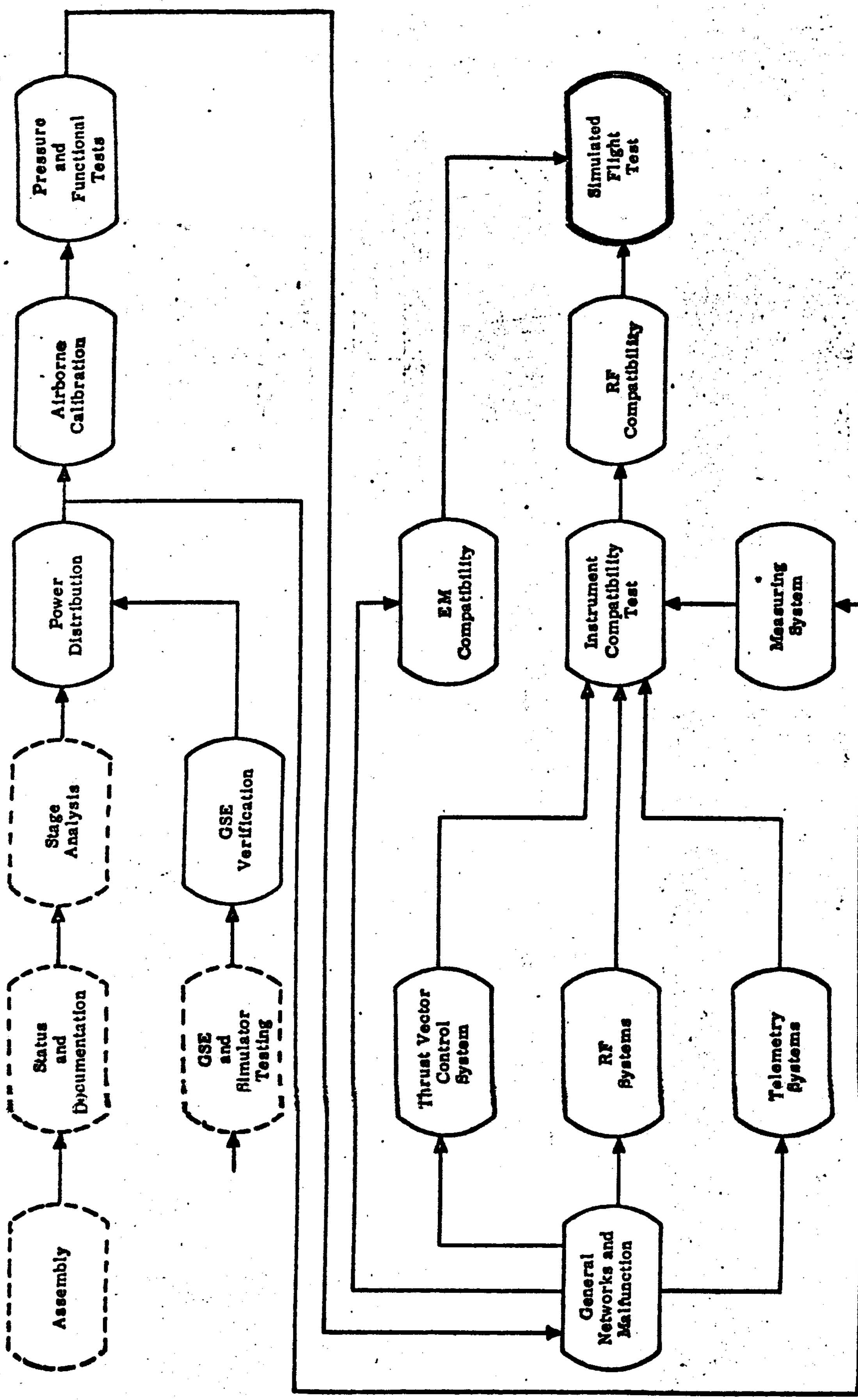


Fig.1.1 Manufacturing Checkout Flow for an Assembled Stage

(Pre/Post Static)

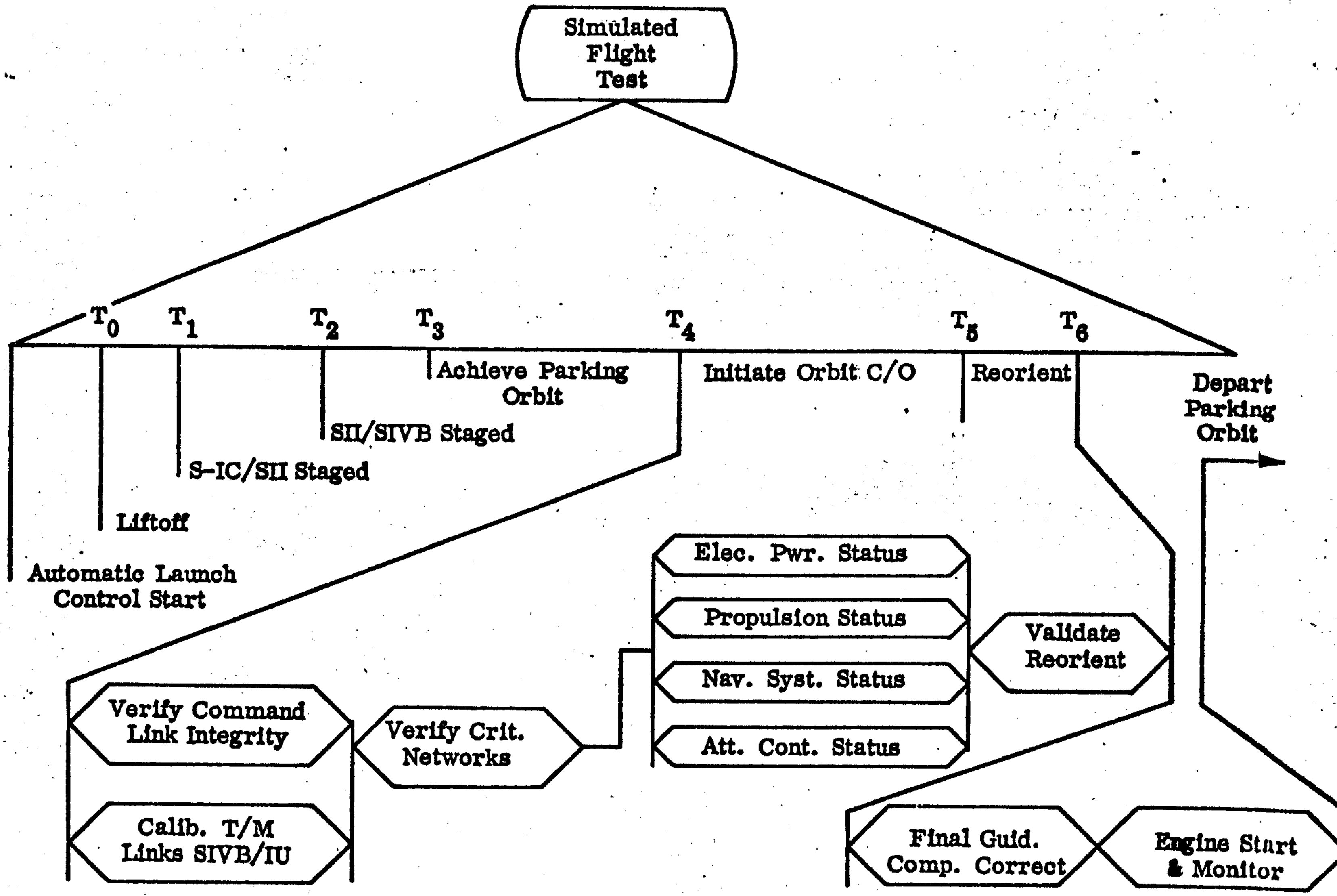


Fig.1.2 Manufacturing C/O of Orbital Operational Stages (Preliminary Sequence)

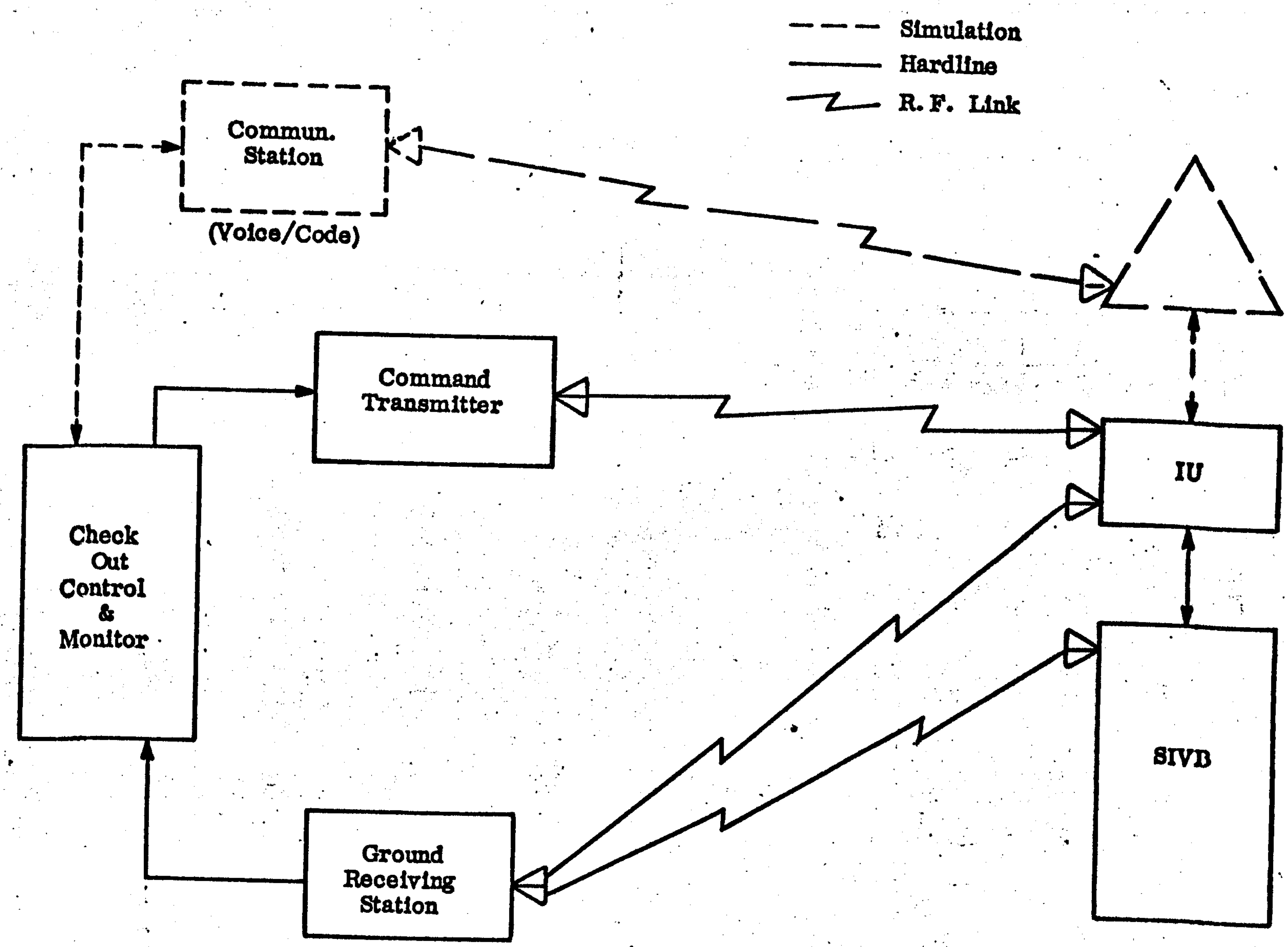


Fig. 1.3 Test Configuration for Manufacturing Checkout of Orbital Operational Stages Simulated Flight Test-Plug Drop

As an initial point of departure the capability for a mated IU (V) - SIVB checkout to be conducted remotely using nothing but on board capability and R.F. links to the checkout station was examined. From this and knowledge of the status of the S-IVB and IU (V) systems, following successful establishment of the parking orbit and just prior to departure, an outline of desirable post manufacturing checks of individual line items of Figure 1.2 was constructed as well as a list of deficiencies of current hardware to accommodate these checks. A study was then made of the problems which arose from assuming that checkouts of the S-IVB and IU might be performed separately and with stage simulators rather than in a mated configuration.

In pursuing the second course of action, the guideline requirements of SR-QUAL-64-13 "Space Vehicle Stage Analysis and Checkout Guidelines", Section 7.10.3 were reviewed item by item to identify those which are compatible with a stage which is fueled, pressurized, and inaccessible except through an R.F. link, and those which are highly desirable even though incompatible with this configuration. The results of this review were correlated with the findings from the first course to avoid oversights in the first set of findings and to provide a complete set of requirements having major hardware impact for use in later phases of this contract effort.

In carrying out the first course of attack a number of stage/IU features were considered. Among these are the wet and pressurized conditions of the S-IVB on orbit, the memory capabilities of the IU, both in the computer and on board tape recorders, the number of equivalent hardline paths between the S-IVB and IU, the possible ease of interconnecting S-IVB and IU DDAS.

The effects of real time delays in signal transmission between an orbiting vehicle and ground stations, and time limitations of ground stations access to the orbiting assembly over R.F. links will be considered in later study phases.

5.0 CONCLUSIONS AND RECOMMENDATIONS*

Conclusions and recommendations resulting from the study of post manufacturing test requirements of the S-IVB and IU stages are contained in Chapters 2 and 3 which discuss the studies conducted on those stages, and in Chapter 4 which is a study of the desirability of performing post manufacturing checkout on the mated stages. Listed below are the major findings of these studies.

- A major consideration in validating orbital checkout capability is verification of ground or IU borne computer programs on which decisions to commit to lunar injection are to be based.
- Immediate design consideration should be given to the use of the LVDC equipment for both the IU and S-IVB checkout.
- To implement the use of the LVDC as a checkout tool the system design should permit data to be furnished to the LVDC via the S-IVB and IU DDAS systems.
- Orbital checkout provisions would best be simulated and their adequacy verified by checking them between first and second burns of a multiple burn static firing of the S-IVB mated with a flight IU.

  Checkout data should be reduced in real time and evaluated prior to initiation of second firing.

*Validity of some conclusions regarding manufacturing checkout has not been fully established since not all S-IVB systems test requirements could be made available for the study.

Additional findings which substantiate or expand on the major findings are:

- Introduction of S-IVB data into the IU through the DDAS system will enhance the efficiency of orbital checkout and permit obtaining increased confidence in the validity of on board checkout functions prior to launch.

- Lack of plans to introduce flight IU to its assigned S-IVB prior to final vehicle assembly seriously handicaps the ability to make a dependable factory checkout of orbital checkout routines and to establish electro magnetic compatibility of the IU and S-IVB.

- The impact of these conclusions on the requirements for functional simulation in the unmated checkout of both the IU and S-IVB led to recommendations in each chapter, that a checkout in the mated condition be performed prior to delivery of the two stages to the launch site.

- Orbital checkout of the current S-IVB will be essentially equivalent to current Agena practice and limited to the following areas:

  Status of significant components such as valves and relays to insure that the vehicle is in the desired condition.

  Evaluation in real time of engine performance during first burn to establish specific impulse realized during that phase.

  Determination of expendable stores remaining to insure sufficient on-board capacity for completing mission.

  Operation of the engine gimballing system to determine its responses.

- A check of orbital checkout procedures at the manufacturing site will add little knowledge regarding the ability of the stages to be properly checked out on orbit since no propellants will have been tanked and no engine operating environments imposed during the total checkout sequence.
- Ampere hour meters should be used to measure electrical consumption in addition to the present method of measuring line current.
- A positive indication of the removal of the LH_2 bias circuit should be provided by using the connection at the Propellant Utilization Electronic Assembly (Ref. DAC Dwg. 1A59353 Sheet 4).
- Provisions should be made to perform in-flight calibration each time the orbiting telemetry transmitters are energized.
- The orbital checkout of the S-IVB can be accomplished from the commands available to the S-IVB from the IU.
- Determination of the current status of expendables, particularly propellants, is one of the most critical requirements of orbital checkout and is also one which, in the current configuration, is not performed in the most satisfactory manner.
- The ascent tape recorder does not have adequate capacity to cover on orbit T/M transmission blind spots to assure detection of intermittent events.
- Barring provision of a star tracker or horizon sensor in the IU, adequate reference for determining on orbit drift of platform axes is not available except through comparison of ground computed ephemeris with LVDC computed ephemeris.

- No deficiencies in currently planned IU (V) factory checkout were found except for the lack of adequate S-IVB/IU DDAS interface verification. Though other shortcomings noted previously are a matter of concern for orbital checkout, available information on factory checkout does not indicate any impairment in factory checkout arising from them.
- These conclusions and recommendations include the only areas in which changes in post manufacturing checkout are considered feasible without a major change in vehicle design. In particular the present design of mechanical systems and components do not lend themselves to orbital checkout other than statusing.
- Significant alterations in procedures only would violate existing guidelines for checkout of assembled stages.

The recommendations embody the changes in system design and post manufacturing test philosophy which are permissible under the restraint of the first phase of this study.

With the removal of the restraint of "only minor equipment changes permissible in existing designs", Phase II will concern itself with recommendations for more extensive vehicle and ESE design changes. Among the areas to be studied are:

- Improved methods of measuring on board propellants.
- Improved methods of measuring status of charge for storage batteries.
- Methods of checkout of mechanical systems and components.
- Development of a technique for the continuous evaluation of operational systems and components in order to determine that system degradation has not degenerated to an unacceptable level.

- o Detail means for using LVDC in factory checkout of the S-IVB as well as the IU.
- o Necessity and/or desirability for "0" g simulation during post manufacturing check of orbital checkout procedures.
- o Adequacy of accuracy of current checkout equipment as regards dynamic measurement.

The results of the above studies will probably be a recommendation for redesign of equipment and systems to be used in orbiting vehicles in order to facilitate checkout both in orbit and during the post manufacturing phase.

6.0 COMPARISON OF S-IVB/IU WITH AGENA

6.1 Orbital Checkout

A marked similiarity exists between the Agena and S-IVB/IU with regard to orbital checkout. As noted previously design of the vehicles precludes exercising the assemblies for purposes of checkout with some exceptions. These exceptions are primarily in areas of command sequencing and attitude control. In even these instances restrictions will exist due to particular mission operations or limitations of stores of consumables. Mechanical systems and controls related to primary propulsion in both instances are amenable only to status determination, except, of course, when actually performing in support of a mission.

However, there is a significant difference between the Agena and the S-IVB/IU assembly as regards complexity which can give rise to major orbital checkout differences. Agena primary propulsion is a hypergolic, boot strapped, passive propellant mixture control system. Start and stop sequences are straightforward with integral sequence control. Inertial reference system is strap down, attitude is monitored by horizon sensors, and on board navigational computations are minimal, usually being restricted to increments of longitudinal axis velocity. Preponderance of navigation functions performed are in response to ground commands relating to timing, attitude, and velocity to be gained. Differences in orbital checkout will arise then, not from philosophical differences in approach, but rather the greater complexity of S-IVB/IU assembly.

6.2 Manufacturing Checkout

Manufacturing checkout of Agena contains little that can be peculiarly associated with orbital checkout. Status determination via telemetry and command verification are the sole features requiring verification in manufacturing checkout. Except in instances of serious operational difficulties the exigencies of orbital checkout have had negligible influence on the manufacturing checkout of Agena. However, such status determination and command verification as is essential to orbital operations is an integral part of the all systems flight simulation tests, as well as prior subsystem and system tests.

With regard to configuration there is a marked difference between Agena and the S-IVB/IU which affect nature and efficiency of manufacturing checkout. There is not, on Agena, a physically separable stage containing navigation and autopilot controller in the sense that the S-IVB and IU are separable. The basic stage for delivery includes propulsive, electrical networks, navigation and attitude control, and telemetry in a single vehicle. Thus manufacturing checkout of Agena automatically encompasses all features which could be realized if manufacturing checkout of the S-IVB and IU were conducted with stages mated. In addition, any captive firing conducted on an Agena is conducted with all flight navigation, command and control, and telemetry systems on board, providing realistic test conditions for validating all systems performance.

There is as well a fundamental difference in approach between manufacturing checkout of assembled Agenas and assembled Saturns. When Agena is completely assembled manufacturing checkout tests tend to be end to end and loop checks more often than is indicated to be the case by currently available Saturn documentation. This is so since heavy reliance is placed on results of earlier tests conducted in the course of component and subsystem checks as well as part of installation operations. Systems are so designed that if end to end tests are unsuccessful, the level of stimulus and response can be carried to that typical in Saturn.

Another difference in approach is that automation in Agena programs has extended but little into the field of test stimulus and control, mainly on account of configuration differences associated with the large variety of missions. On the other hand Agena programs are heavily committed to automatic high speed data reduction to provide rapid post test analysis as well as current test status. While time spans for vehicle checkout are by no means very short, they are in major part paced by vehicle response capabilities. On the other hand, Agena experience was that data recution required undesirably long times. Not infrequently two weeks or more were required to obtain necessary reduced data from which further analysis and actions leading to decision for positive release of the vehicle for transfer could be made. In the interim the vehicle was in suspense, withheld from any approved change activity, occupying storage space, if not actually tieing up a test bay, and, if stored, requiring special provisions for environmental protection. With this kind of experience the decision in Agena programs was to first automate the data reduction processes, reducing spans for reduction and easing the analysis effort, and limit automated stimulus and control to relatively slow punched paper tape drive through relay matrices. Future planning does include increasing the degree of test control automation, but only when assurance exists that it can be done economically in the face of highly variable test article configuration.

Agena on orbit experience is quite useful in assessing orbital checkout consideration for the S-IVB/IU assembly. However, major differences in test article configurations and test equipment and approach, tend, in general, to limit a comparitive evaluation toward C/O improvement.

CHAPTER 2

CHECKOUT OF THE S-IVB

1.0 CONCLUSIONS AND RECOMMENDATIONS

1.1 Conclusions

1.1.1 The design of the Saturn S-IVB, which has been defined as the reference vehicle for the study (a), limits the amount of orbital checkout that can be performed on the vehicle without major changes in vehicle equipment. As a result orbital checkout will be essentially equivalent to current Agena practice and limited to the following areas:

- o Status of significant components such as valves and relays to insure that the vehicle is in the desired condition.
- o Evaluation in real time of engine performance during first burn to establish specific impulse realized during that phase.
- o Determination of expendable stores remaining to insure sufficient on-board capacity for completing mission.
- o Operation of the engine gimballing system to determine its responses.

1.1.2 Validity of the checkout of orbital checkout procedures while at the manufacturing site is weakened by inability to simulate boost and orbital environments. During the phase of post manufacturing checkout which includes a systems test, all operable components are exercised, all measurement devices are calibrated, correct measurement/readout relationships are verified, and system operation is evaluated. This is an equivalent procedure to the prelaunch checkout of the launch vehicle and is much more detailed. A simulated boost and first burn is then performed, followed by the orbital checkout phase - but as no propellants have been tanked and as no flight environments have been imposed; the only check is of the program that returns the systems to the orbital coast mode.

1.1.3 Increased confidence in orbital checkout results will obtain if the simulated orbital checkout of the stage is performed following the first of a multiburn static test of both stage and engine. The checkout techniques and instrumentation for expendables would be verified as well as the ability to evaluate system degradation due to engine operation.

1.1.4 The report of Douglas on the requirements for orbital checkout of the S-IVB (b) defines the required vehicle status for orbit and also lists the flight telemetry available for checkout. The conclusions and recommendations presented by Douglas in this report are quite complete and are accepted for orbital checkout. There are only two areas where changes are desirable:

- The use of on-board ampere hour meters will facilitate the real time evaluation of state of charge of the batteries.
- There is no positive indication of the elimination of the fuel bias circuit after first burn. This information is to be deduced from the "Summing Point Error" signal (Measurement N5). However, as this line is at ground potential unless the PU activate signal has been given, (Ref. DAC Dwg. 1A59353 Sheet 4) the status of the bias is unknown during orbital checkout.

1.1.5 The orbital checkout can be accomplished from the commands available to the S-IVB from the IU. The commands which are transmitted through the switch selector are contained in Appendix 3.

1.1.6 Determination of the cureent status of expendables, particularly propellants, is one of the most critical requirements of orbital checkout and is also one which, in the current configuration, is not performed in the most satisfactory manner.

1.1.7 Validity of some conclusions regarding manufacturing checkout has not been fully established since not all S-IVB systems test requirements could be made available for the study.

1.2 Recommendations

1.2.1 Conditions for Validation of Orbital Checkout Procedures. It is recommended that the orbital checkout procedures used with the S-IVB be validated as follows:

- Orbital checkout procedures should be performed on a stage which is being subjected to a multiple start hot firing. The orbital checkout procedures should be performed after each engine cutoff and prior to restart. This checkout should be conducted with ESE that is typical of that which will be used at the launch site and/or down range stations during the actual orbital checkout. Equipment and controls which are not typical of those to be used during operations should be used as backup but should be employed only to ensure that all safety requirements are met.
- All flight hardware should be installed for this checkout phase.
- Checkout data should be reduced in real time and evaluated prior to initiation of second firing.
- Telemetry calibration should be performed each time the orbiting telemetry group is turned on.

- The flight IU should be mated with the S-IVB.

The above recommendations cover the checkout procedures that will provide optimum results during factory checkout. Checkout under less ideal conditions can be performed. The results of the S-IVB testing under conditions other than those proposed is discussed in later sections. Chapter 4 discusses the problems of interface evaluation if the IU and S-IVB are not mated during evaluation of orbital checkout.

1.2.2 Telemetry. The flight telemetry system should be modified as follows:

- Ampere hour meters should be used to measure electrical consumption in addition to the present method of measuring line current.

- A positive indication of the removal of the LH_2 bias circuit should be provided by using the connection at the Propellant Utilization Electronic Assembly (Ref. DAC Dwg. 1A59353 Sheet 4).

- Provisions should be made to perform in-flight calibration each time the orbiting telemetry transmitters are energized.

1.2.3 Performance Evaluation. The body of this report shows the desirability to develop in Phase II, a system for evaluation of the last recorded performance of a system or component against a predicted normal performance based on all available data as to initial value as modified by a predicted degradation rate. This procedure will, in effect, provide confidence of the ability of the item to operate properly during the next operation. In order to implement this concept of checkout, an extensive test plan and a well organized data storage and retrieval plan must be used. It is recommended that, although the proper sensing and measuring systems are not available in the S-IVB, immediate steps be taken to devise and put into operation such a test plan and data system.

1.2.4 Future Studies. The recommendations for studies to be undertaken in Phase II are contained in Section 3.0 of this chapter.

2.0 S-IVB SIMULATION OF ORBITAL CHECKOUT DURING POST MANUFACTURING CHECKOUT

2.1 General

The requirements for the post manufacturing checkout of an assembled stage are discussed in Section 7 of "Space Vehicle Stage Analysis and Checkout Guidelines". (c) Three general test objectives are listed (paragraph 7.5). Orbital checkout is concerned with two of the three objectives listed for the post-captive checkout phase of manufacturing checkout. These two (modified slightly to make them applicable for orbital checkout) are: To determine that the stage has not deteriorated as a result of boost and first burn; and to validate the functional capabilities of those systems which will be required to operate during the remainder of the mission. To this must be added the objective of the establishment of proper vehicle condition for initiation of second burn.

Orbital checkout is unique in that it must take place under the following conditions:

- o The checkout must be conducted within the limitations of R.F. communications with the ESE, except for the limited on-board provision for storage of commands and data. Supplemental commands may also be available from the Command module in an Apollo mission.

The on-board commands available from the Saturn IU through the switch selector system are listed in Appendix 3.

- o The checkout must be conducted on a stage which is fueled, pressurized, and with some equipment either actively operational or which must be kept in an immediate ready standby condition.
- o Energy expended during checkout will not be available during the ensuing mission phase.

Post manufacturing checkout must be defined so as to substantiate the validity of orbital checkouts conducted under these conditions.

Douglas Aircraft Company has published a study on the requirements for orbital checkout of the S-IVB. (b) This study envisions monitoring the status of several key parameters and exercising only the engine slewing sybsystem. These conclusions were based on certain ground rules (Table 2.1). The manufacturing checkout concept developed herein is based essentially on these ground rules and on additional assumptions which are peculiar to the manufacturing checkout phase. The additional assumptions are also listed in Table 2.1.

TABLE 2.1

GROUND RULES FOR POST MANUFACTURING CHECKOUT FOR ORBITAL STAGES

A. Ground Rules for Orbital Checkout as proposed by Douglas Aircraft Co. (b)

1. Checkout is based on present orbital coast time - maximum of $4\frac{1}{2}$ hours and 2 hours translunar coast.
2. No provisions to be made for orbital maintenance, i.e., astronauts will not leave the command module to perform repairs.
3. Orbital checkout to be accomplished in either manned or unmanned missions.
4. Maximum use of the Instrument Unit (IU) on-board computer will be made.
5. The IU computer is assumed to have ground command capability.
6. Orbital checkout will be on a real time basis.
7. Hardware redundance over present design will be considered only as a last resort.
8. Additional weight added to the stage will be kept to an absolute minimum.
9. The Mercury/Gemini tracking network, as modified for Apollo, is to be utilized for orbital checkout.
10. Ground computers and associated telemetry ground station, located at tracking stations, will be available for orbital checkout evaluation.
11. Stimuli signals, if required, will come from Instrument Unit to sequencer via switch selector.

TABLE 2.1 (CONT'D)

B. Additional Ground Rules for Post Manufacturing Checkout Phase:

1. All commands and stimuli must be given in the same manner as in orbital checkout.
2. Computer programs prepared for computers at manufacturing sites should be translatable to programs suitable for computers used at launch site and tracking stations.
3. Proper operation of all equipment from the component to system level is assured in the preflight phase of the countdown.

2.2 Checkout Sequence

Three test objectives for orbital checkout have been listed in a preceding paragraph. Post manufacturing checkout sequences designed to ensure the accomplishment of these three objectives cannot be defined uniquely without considering the conditions under which the checkout occurs. These conditions could be:

a. Between first and second burns of a captive firing.

b. Between fill and complete drain of a cold-flow operation.

c. After the vehicle has been moved from the captive test stand but before it has been attached to normal ESE.

d. After the vehicle has been moved from the captive test stand and is attached to normal ESE. (Final Factory Test)

e. Before the vehicle has left the factory for static test.

The condition described in a. above has many advantages. It most nearly duplicates the conditions of orbital checkout; it performs checkout on equipment that has been subjected to the thermal and mechanical stresses associated with engine operation; a checkout of some degree after shutdown will be required if a multiburn firing is performed, therefore, the orbital checkout can be used to fulfill part of this requirement and actual propellant utilization data can be used for first burn performance analysis. The major disadvantage of this mode of operation is that the proper equipment (computer and TLM ground stations) may not be available at the site, and the vehicle may not be in flight configuration.

Performing orbital checkout during a cold flow run would evaluate the propellant utilization system but the stresses associated with engine firing are not present. Flight sequencing accompanying cold flow would ensuring that the vehicle was programmed properly so that all equipment would be in the desired configuration for orbital coast but all engine performance and flight dynamic data would have to be simulated. As the stresses of engine operation would not be present these would have to be ignored or provided as preconditioning on individual stage equipment.

Checkout of a vehicle after captive test but before connection of normal ESE will show the ability of a R.F. link to evaluate fully the effects of first burn stress on the equipment which was installed during captive test. However, this method of checkout will not evaluate the Propellant Utilization Unit, nor will it be too effective if the captive test vehicle does not have a complete complement of flight type equipment. In removing the vehicle from the test stand the status of the vehicle will be significantly altered so that testing under these conditions is completely impractical.

Waiting for normal ESE and checkout has no virtue that is not attributable to one or more of the other methods of checkout except convenience and assurance that before the vehicle is finally released all flight equipment will be on board. However, it is probable, at least during the early portions of a vehicle program that this will be the mode in which the orbital checkout phase of factory checkout will be conducted. All flight parameters will have to be simulated in order that any meaningful orbital checkout may be investigated.

Performing a simulated orbital checkout during the post manufacturing checkout of the vehicle prior to a static test has no particular advantage as it will follow the same procedure as the post static test.

The checkout at this time may be of less value than a similar one after static firing and just prior to shipment from the factory as all systems may not be installed for the static test.

2.3 Systems Concerned with Orbital Checkout

Only those subsystems and systems which will be used during subsequent operations need to be checked out. As defined by DAC, these are:

- o Propulsion System
- o Engine Gimbal System
- o Electrical System

To these should be added the instrumentation systems.

2.3.1 Objectives for Checkout of Propulsion System. The propulsion system is the main system of concern during orbital checkout. It has operated to inject the stage (s) into the coasting orbit and then shutdown. Before the second operation of this stage the following things must be determined:

- o Actual performance of the engine during first burn
- o Propellants left on board vs propellants required to continue mission
- o Engine controls in a restart configuration
- o Pressurization fluids on board

In addition the following information would be desirable before committing the vehicle to the transfer orbit:

- o Full operability of essential valves
- o Integrity of plumbing
- o Proper operation of all transducers
- o Proper operation of propellant utilization system, including main pumps

DAC recommends the limiting of orbital checkout to the four items listed as "must". Their method of doing this and the implication of their decision on the manufacturing test sequence will be discussed later. For the other parameters, DAC is satisfied to monitor valve position and accept the prestart chilldown sequence as a check of the propellant utilization system.

Of the four "must" conditions, two will present no unusual problems during stage checkout or will add no requirements for extensive provisions for for flight simulation. The "Engine Ready" signal on both hardline and TLM transmission to ESE will establish that all restart conditions have been established on the engine control system including the proper recharging of the starting tank. The amount of pressurization fluids remaining on board will be established by pressure/temperature relationships in the storage spheres. There are sufficient TLM signals to satisfy this requirement for stage checkout, in addition hardline backup circuits will establish the validity of the TLM signals.

2.3.2 The establishment of first burn performance is most essential. Two methods have been proposed in the DAC checkout paper.

- o Calculation of performance from tracking data
- o Calculation of performance, from propellant mass flow, pressure, and temperature information

Both of these methods require the use of a ground computer for real time data reduction. The programming of the computers which are based at KSC and other tracking stations may not be validated directly during factory checkout; however, simulation of the origination, conditioning and transmission of the data required for these computations can be performed for the purpose of verification of proper operation of stage mounted equipment. The program used for the factory checkout may be transferred to the tracking computers without further validation provided there is sufficient confidence in the translator. The Launch Vehicle Digital Computer (LVDC) may be asked to perform these functions if they are within its capability. This computer could be used either alone or in conjunction with a ground based computer. The method of performance of post manufacturing checkout is most critical for this phase of checkout. If it is done between multiple burns of a actual firing, performance of the engine from propellant flow data can be calculated from actual data. A performance check from tracking data can be performed by measuring actual thrust, (corrected for altitude) and simulated headings as measured by amount and duration of actual engine gimballing.

The thrust and heading measurements can be translated by a computer into boost trajectory and orbit insertion data to establish a theoretical orbital position. The use of the theoretical orbit position, the real time analysis of first burn performance as established by measured engine parameters, and the calculations of propellants remaining will thoroughly test the ability of the ground computer and/or the LVDC to compute and compare the two sources of performance data, to establish the propellant requirements for mission completion and to make a go-no-go decision based on these calculations. The IU or an IU simulator with LVDC capabilities will have to be part of the test configuration if this mode of checkout is used and the LVDC is being used for these computations. Vehicle measurements required to evaluate the engine performance are listed in Table 2.2.

TABLE 2.2

PARAMETER	FLIGHT MEASUREMENT IDENTIFICATION
ENGINE PERFORMANCE EVALUATION	
Thrust Chamber Pressure	D-1
Fuel Pump Inlet Pressure	D-2
Oxidizer Pump Inlet Pressure	D-3
Fuel Pump Inlet Temperature	C-1
Fuel Flow	F-2
Oxidizer Flow	F-2
FLIGHT SIMULATION EVALUATION	
Test Stand Strain Gauges (For thrust computation)	(Unidentified)
Pitch Actuator Position	G-1
Yaw Actuator Position	G-2

2.3.3 Checkout under conditions of post captive test back at the factory can evaluate only the effects of the vibration and temperature of the first burn environment have upon the vehicle components. The safety requirements for moving the vehicle from the test stand to the checkout area will certainly not leave the vehicle system in a "ready" condition for second burn, so evaluation of valve and switch positions will be meaningless.

If no engine performance data is available from static firings, then engine performance data must be simulated as well as flight data. The simulated data will have to be coordinated so that logical go or no-go decisions can be made by the computers operating on this data.

2.3.4 Whether the source of the engine/stage performance data is simulated entirely or is derived in part from captive test data, the computer representing the ground station will be required to perform the following tasks:

- o Calculate maximum total impulse required to complete mission
- o Calculate minimum propellant available for mission completion
- o Calculate minimum engine performance from first burn data
- o Calculate minimum total impulse left based on worst on worst calculations
- o Provide proper go no-go decisions with reference to these parameters and indicate margin (deficit)

2.3.5 Other systems and subsystems associated with the propulsion system must also be checked out. Status monitoring of key components is all that DAC recommends for orbital checkout. However, to the extent that these systems have been operated in the first burn phase, past performance data will be available from telemetry. Operational effectiveness of these systems can be evaluated by comparing actual performance to predicted performance. For instance, a valve, even though only two position (completely open or completely closed) might be evaluated in terms of transit time between open and closed states during first burn cycling. Thus even though the valve is found to be in the proper "status" during orbital checkout;

further information as to its performance would be available. All phases of checkout must be used to establish normal operational parameters for systems and components. The major tasks in assembling this information are:

- o An extensive test program beginning with factory acceptance tests and including such environments as are not destructive. The data secured will be used to establish performance norms and acceptable deviations. This information will then be used for go no-go decisions.
- o Accurate identification of test data with the item under test.
- o A system for rapid and accuarte collation, evaluation and dissemination of test information.

Because of the limitations of the ground rules established, full implementation of this technique may be impossible because of the lack of necessary instrumentation on the current flight vehicle. However, implementation of the ground test program and data handling methods should be incorporated into existing programs as rapidly as possible.

TABLE 2.3

PNEUMATIC CONTROL SYSTEM	
LOX Vent and Relief Valve	(K-2; K-16)
LH_2 Vent Relief Valve	(K-1; K-17)
LOX Propellant Shutoff Valve	(K-109; K-110)
LH_2 Propellant Shutoff Valve	(K-111, K-112)
Fuel Directional Control Valve	(K-113)
Continuous Vent Valve	(Not identified)
Ambient Helium Storage Pressure	(D-87)
He Pressurization Sphere Temperature	(C-205)
Fuel Vent Valve Pressurization Supply	(D-14)
AMBIENT HELIUM SUBSYSTEM	
Fuel Tank Ullage Pressure	(D-21)
Ambient Helium Storage Pressure	(D-20; D-88)
Oxidizer Tank Ullage Pressure	(D-22)
COLD HELIUM SUBSYSTEM	
Cold Helium Storage Pressure	(D-16)
Cold Helium Storage Temperature	(C-208)
MAIN TANK INTEGRITY	
LOX Tank Pressure	(D-22)
LH_2 Tank Pressure	(D-21)
J-2 ENGINE SUBSYSTEM	
Engine Ready Signal	(K-12)
LH_2 Childown Flowmeter	(F-5)
LOX Childown Flowmeter	(F-4)

2.3.6 In all of these parameters, factory checkout beyond countdown and simulated flight will not be meaningful, unless the checkout or orbital parameters is conducted between static firing. The various transducers will be calibrated during the countdown phase and the connections to the proper telemetry channels will be verified. Further investigation after a simulated flight will yield little additional data. Only valve status as commanded by the flight sequencer and/or IU command unit need be checked to verify the programs developed for these units.

2.4 Attitude Control System

The attitude control subsystem will be active during the coast phase. Evaluation of its performance will be part of the overall attitude control system including the sensing and command components. During post manufacturing checkout of the engine portion of the attitude control system mounted on the S-IVB vehicle, all transducers, valves, propellant and oxidizer storage spheres will be checked out at the time of countdown. No additional information would be gained by performing additional checks during the simulated orbital phase unless it was conducted between static firings. If the checkout is conducted at that time, actual thrust response to IU commands can be evaluated by test stand instrumentation. However, the potential sensitivity of on orbit limit cycling phenomenon to apparently minor changes in component gains and accuracy may require increased precision in factory checkout of those components involved in the attitude control loop. Analysis of this problem in depth could not be carried on in Phase I. It will be an appropriate part of the Phase II analysis of checkout functions assignable to the LVDC.

2.5 Engine Gimbal System

The objectives in checking the Engine Gimbal System while in orbit are:

- o To ensure the mechanical integrity of the system
- o To ensure sufficient operating fluids remain in the system
- o To evaluate the dynamic response of the system

The mechanical integrity of the system and the amount of operating fluids are determined by pressure and temperature readings. Dynamic response can be evaluated by programmed commands from the IU with the gimbal movement being analyzed from telemetry signals. The amount of dynamic testing to be done in orbit is a function of the amount of stored energy that can be expended in executing the tests.

The factory checkout of the orbiting checkout phase of the gimbal system is subject to limitations similar to those found in the checkout of the propulsion system. The system will be thoroughly checked out during the preparation and countdown phases of either a hot firing or a simulated firing. The ability of the selected parameters to give the desired status information can be thoroughly evaluated in conjunction with a static firing. If the checkout of orbiting checkout procedures is performed only after a simulated flight, no additional information will be gained by the artificial stimulation of transducers or the further exercising of the actuator system.

2.6 Electrical System

The objectives of orbital checkout of the Electrical System are:

- o To evaluate the state of charge left in the batteries
- o To ensure that the status of all circuits is as required

by orbiting requirements

- o To ensure that battery temperatures are within operating limits
- o To evaluate the integrity of the electrical busses

The orbital checkout of the electrical system differs greatly from the normal post manufacturing checkout because it is not necessary to verify connection to ESE, replacement of connectors removed for test purposes and incorrect wiring which may damage equipment, as all of these will have been accomplished prior to launch. The orbital checkout will be used to establish the amount of energy left in batteries, the proper switching of circuits and detection of gross circuit to circuit to ground faults. The normal telemetry information planned for the S-IVB is satisfactory for orbital checkout except for the most important function - establishing the level of charge left in storage batteries. The present method assumes a given ampere hour charge at launch and monitors bus current drain. The TLM data then is integrated at the ground station and the ampere hours remaining are computed. There are three basic problems associated with this procedure.

- o The assumed initial charge may be in error
- o Loss of TLM data may make data reduction grossly inaccurate
- o The integrating and computing process is time consuming

There is no practical method, in the present state-of-the-art to determine the state of charge of a silver zinc battery, so the first problem cannot be eliminated. However, flight type ampere hour meters are available with digital readout. Substitution of this for the shunt now used will permit transmission of the totalized data. Loss of data because of temporary failure of TLM transmission will not be a factor as total ampere hours consumed will be transmitted as soon as the R.F. Channel is working normally. All integrating and computational requirements will be eliminated thus reducing the problem of real time data reduction. The post manufacturing checkout of the electrical system will more nearly approach orbital checkout than any others, even if conducted in a non-firing environment. Actual electrical loads and power consumptions will be very close to that to be experienced due to boost and orbital operation. Switching programs, whether they are stored or in response to actual or simulated stimuli can be validated. Also any malfunction due to EMI or incompatible operating modes during orbit and second burn may be discovered and eliminated.

Parameters to be checked in the Electrical System are listed in Table 2.4.

TABLE 2.4

Current Forward Batteries #1 & #2 or ampere hours	(M-19; M-20)
Temperature Forward Batteries #1 & #2	(C-102; C-103)
Current Aft Batteries #1 & #2 or ampere hours	(M-21; M-22)
Temperature Aft Batteries #1 & #2	(C-104; C-105)

2.7 Telemetry and Instrumentation Requirements

During orbital checkout the instrumentation and telemetry system will be actively employed in data collection and transmission. Provisions are available for in-flight calibration of all channels. In-flight calibration is presently commanded approximately 400 seconds before SII S-IVB separation and again just subsequent to second burn cutoff. As flight calibration can be commanded through the IU and switch selector circuits 62 and 64, it is recommended that it be repeated each time the orbital transmitter group is turned on. No change will be required in the existing post manufacturing checkout procedures associated with this system.

2.8 Vehicle System Requirements

Normally the post manufacturing checkout of a flight stage requires only the individual stage itself. Stimuli or signal response which, in flight, are produced by other flight stages are furnished by appropriate stage "simulators". For checkout of the S-IVB assigned to an orbital mission, this simulation may not be satisfactory for the IU. In Section 2.3.2 the use of the LVDC was suggested to perform the computations required to evaluate first burn performance. In their report on orbital checkout, DAC suggested that the orbital checkout parameters be transferred to the IU PCM system because of its UHF capability. Confidence in the factory checkout of the S-IVB would be enhanced significantly if it were conducted in conjunction with the IU assigned for the flight as the debugging of the critical communications and control interface could be performed at this time rather than at the launch site. A more detailed study of the desirability of mating the IU for checkout is contained in Chapter 4.

Systems involved in orbital checkout can be exercised by commands originating in the IU and passing through the switch selector. The commands available by this process are listed in Appendix 3.

2.9 Summary - Post Manufacturing Checkout Requirements

Normal post manufacturing checkout conforming to the requirements contained in document "Space Vehicle Stage Analysis and Checkout" (SR-QUAL-64-13) are all inclusive and are sufficient to justify confidence that all systems would operate properly if no further modifications were incorporated or degrading environments were encountered. Orbital checkout procedures will be designed to ensure continued confidence in these systems being operable after the stage has been assembled into the launch vehicle and boosted into orbit. It follows that any changes in requirements for post manufacturing checkout of a stage designed for an orbiting mission will be limited to establishing the validity of the orbital checkout procedures. The recommendations and conclusions listed above are the design and test changes that are feasible to accomplish these revised requirements under the constraint that modifications of existing vehicle design be limited only to minor items. In particular, mechanical components and equipment are not conducive to orbital checkout without major redesign.

3.0 AREAS OF STUDY, PHASE II

3.1 Orbital Checkout

While Phase I of this study limited the vehicle to a current S-IVB with only minor changes permitted, Phase II offers additional considerations; a major redesign of the vehicle to increase the value of orbital checkout and/or the presence of an Orbital Launch Facility (OLF) for checkout, limited maintenance, and replacement of expendable stores. Although the analysis of the Phase I problem has not identified all of the problems to be investigated during Phase II, some very important areas have been defined.

a. Propellant Utilization

One of the major deficiencies developed in the Phase I study is the inability to determine accurately the mass of propellants left on board prior to post orbiting operations. The development of a measuring device which will achieve this purpose will greatly enhance the value of the orbital checkout in the absence of an OLF and will be absolutely necessary to control fuel transfer if an OLF is provided.

b. Electrical System

The use of storage batteries as a prime source of power in advanced vehicles is questionable. Recovery of solar energy or the conversion of nuclear energy will be required in order to support the longer mission lives of these vehicles. However, batteries may still be retained as emergency standby sources. Unlike the lead acid batteries used in automobiles there is no easy test for an alkaline battery corresponding to a specific gravity test. Development of a state-of-charge device would permit evaluation of batteries used for standby so that timely replacement by the OLF would be possible.

c. Mechanical Operational Equipment

Checkout of mechanical operational equipment such as valves, mechanical sensors, and hydraulic or pneumatic equipment is an area which is fertile for development in order to achieve suitable orbital checkout techniques. Many of these cannot be checked after launch as long as propellants and other operational fluids are on board. Time and energy considerations will probably rule out detanking an orbiting vehicle in order to perform a checkout by the OLF, so some technique for performing this checkout with propellants aboard must be developed. In Section 2 it was suggested that a band of acceptable dynamic responses could be established by extensive component testing. The dynamic operational parameters measured at countdown, during launch, and during orbit injection could be evaluated against each other and to the acceptable operational band in order to establish performance evaluation.

d. The use of the Launch Vehicle Digital Computer (LVDC)

The LVDC aboard the IU offers opportunity to reduce the problem of communications between the orbiting vehicle and ground stations. This may be done by programming it to perform one or more of the following tasks:

- o Computation of engine performance
- o Computation of propellants remaining
- o Computation of impulse requirements
- o Data compression of checkout data

A study will be made to determine the capability and desirability of the LVDC being assigned any of these additional tasks. As a collateral study the logistical implication of providing the assigned flight IU in place of an IU simulator will be investigated if the LVDC is to be used for assisting in orbital checkout.

3.2 Post Manufacturing Checkout

The post manufacturing checkout of advanced orbital vehicles will be based on solutions to the problems raised above as well as to the problems brought out in Phase I. Phase II of this study will concern itself with the following areas:

- o Development in greater detail the need for complete historical trace of critical parameters
- o Data storage and retrieval requirements to facilitate the continuous trend evaluation of successive test phases
- o Design of components and transducers to facilitate checkout under limitations imposed by the orbiting environment
- o Techniques to simulate those environments found during boost phase and in orbit which are not present at the factory

CHAPTER 3

CHECKOUT OF INSTRUMENT UNIT

1.0 CONCLUSIONS AND RECOMMENDATIONS

1.1 Conclusions

The following points have developed from the analysis completed in the first phase of the study.

a. The level of information on the IU (V) available during the first portion of the study was rather broad. As a consequence several of the conclusions and recommendations evolved were based, not on positive deficiencies found in the course of the study, but rather on technical needs for which clear cut satisfaction could not be found.

b. The ascent tape recorder does not have adequate capacity to cover on-orbit T/M transmission blind spots to assure detection of intermittent events.

c. Adequate reference for determining on orbit drift of platform axes is not available except through comparison of ground computed ephemeris with LVDC computer ephemeris.

d. Introduction of S-IVB data into the IU through the DDAS system will enhance the efficiency of orbital checkout and permit obtaining increased confidence in the validity of on board checkout functions prior to launch.

e. Lack of plans to introduce flight IU to its assigned S-IVB prior to final vehicle assembly seriously handicaps the ability to make a dependable factory checkout of orbital checkout routines and to establish electro magnetic compatibility of the IU and S-IVB.

f. With the exception of item e. immediately above no deficiencies in currently planned IU (V) factory checkout were found. While the omissions noted in part b., c., and d., are a matter of concern for orbital checkout, available information on factory checkout does not indicate any handicap in factory checkout arising from them. As more detail becomes available on factory test plans for the IU this conclusion may be modified.

In addition it is noted that the following items must be considered in greater depth on the continuing study under this contract:

a. Need for and methods of simulation of zero g and free body mechanics during post manufacturing checkout, particularly as it relates to the stable platform.

b. Complete definition of status and operating sequence of orbiting IU. Inherent limitations on thoroughness of orbital checks, and consequent proper emphasis on post manufacturing checks of orbital capability are sensitive to such definition.

c. The usage of memory capacity for operations from pre-launch checkout through the flight profile in order to assess the impact of storage requirements for orbital checkout: An analysis will be made to improve the estimate of the present memory requirements. The storage capacity for orbital checkout has been estimated to be of the order of 10,000 bits.

d. The division of control of orbital checkout between the LVDC and ground command stations.

e. Instrumentation for monitoring self checking of the LVDC, for determining true attitude position and for determining the condition of non-operating networks.

f. Sequencing of the LVDC between IU checkout, S-IVB checkout, and flight functions other than checkout.

1.2 Recommendations

a. The LVDC should be used as a major piece of test equipment for factory checkout of the IU and the S-IVB. This will evaluate the use of the LVDC as the test computer for orbital checkout and "shakedown" the orbital checkout computer prior to launch.

b. The IU and S-IVB should be mated during factory checkout. This and Item 1.2.a above will minimize the amount of simulation required and will evaluate the LVDC, the IU and the S-IVB as a functional entity.

c. Orbital checkout of the IU should include self-check of the LVDC not only as a prime control element but also as a major systems checkout tool. The use of self-checking of the LVDC would establish confidence in the ability of the LVDC to conduct orbital checkout.

d. A means should be provided to determine the accuracy of the attitude position measurements. Orbital checkout should have the facility to determine if drift has occured in the instrumentation related to attitude positions. The drift could then be corrected at the instrument or as a bias applied to the attitude position parameters.

e. Platform accelerometer outputs and gimbal torquers should be available externally to the IU for processing to establish zero g and trajectory mechanics simulation.

f. Horizon sensors for Saturn V should include a means of heat generation for orbital checkout of the sensors.

g. Use the tape recorder only to store "NO-GO's" during orbital blind spots rather than the actual value of the parameters. This would maximize the storage capacity of the tape recorder, would minimize the amount of data to be transmitted to a tracking station and would reduce the ground data processing time required to evaluate the orbiting vehicle.

h. Install a digital tape recorder in the IU. The ascent tape recorder presently used is an analog type with a recording time of 180 sec. It is necessary that a digital recorder with a recording time of 30 minutes be provided for use during orbital blind spots.

i. The assignment of memory space in the LVDC should include provision for a minimum of 10,000 bits for orbital checkout operations. The text of this note details the manner by which this figure was determined.

j. The IU telemetry system should be calibrated at least once during each orbit.

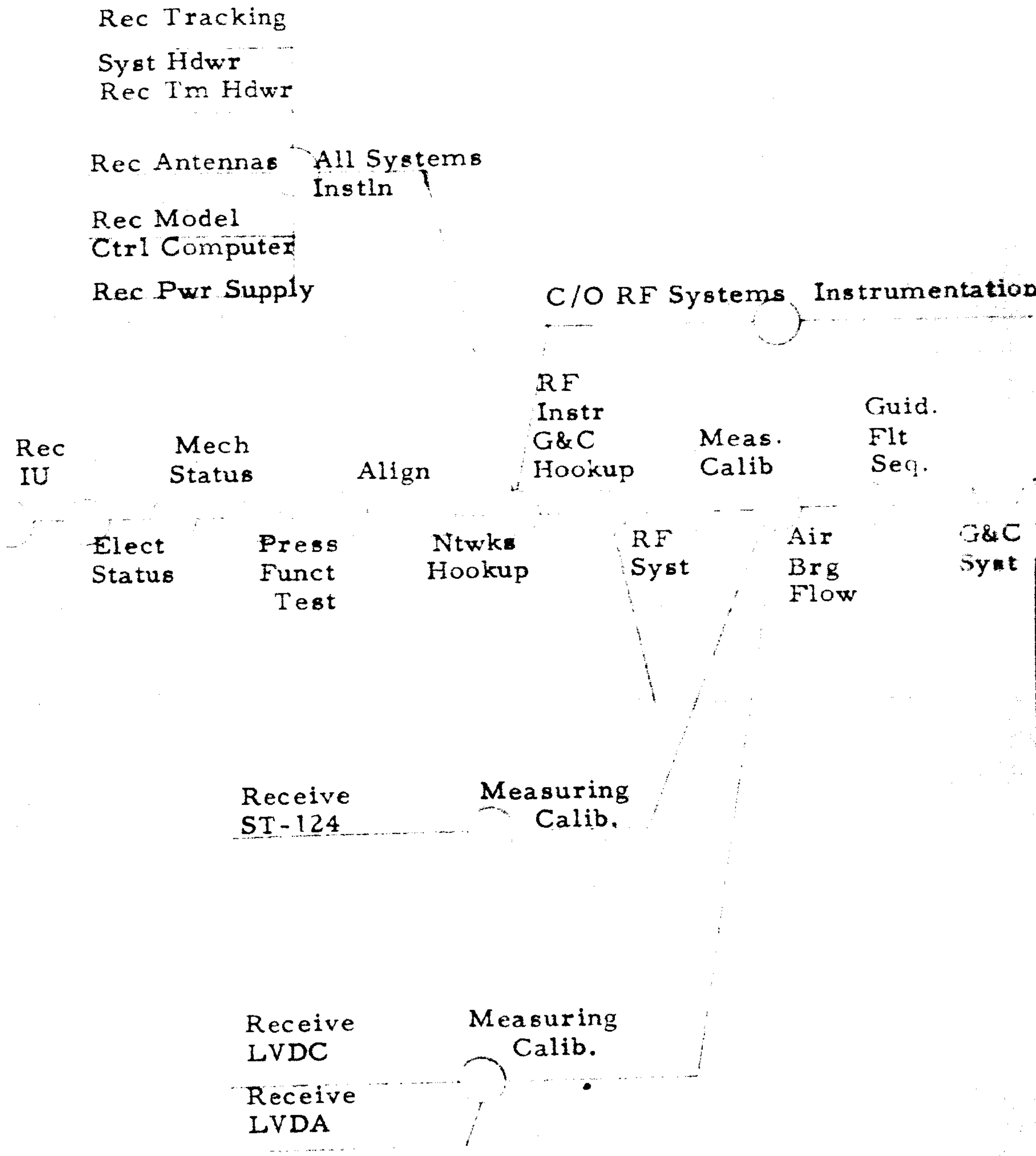
2.0 PRESENT CHECKOUT CONCEPT

The present concept for post manufacturing checkout is a series of tests as shown in Figure 3.1. These tests range from individual subsystem tests to integrated systems tests such as the simulated plug drop and simulated flight tests. The equipment used to perform these tests are listed in Table 3.1 It may be noted that the Launch Vehicle Digital Computer (LVDC) is not utilized in the conduct of post manufacturing checkout except during the tests made upon itself.

The checkout of the IU includes 210 parameters which form a part of the IP&C List. (The list for S-IU-9 was used for this discussion.)

TABLE 3.1
EQUIPMENT REQUIREMENTS
FOR
POST MANUFACTURING CHECKOUT (IU-9)

Launch Control Computer (LCC)	Instrumentation & T/M Recorder Room
C/O Electrical Support Equipment	DDAS
Launch ESE	S-1 Dynamic Simulator (SIDS)
Pneumatic Center	Stage Interface Test Set (SITS)
Networks Station	Accelerometer Tilt Stand Fixture
Navigation Test Station	


Rec Tracking
Syst Hdwr
Rec Tm Hdwr
Rec Antennas
All Systems Instln
Rec Model Ctrl Computer
Rec Pwr Supply
C/O RF Systems
Instrumentation
Rec IU
Mech Status
Align
RF Instr G&C Hookup
Meas. Calib
Guid. Flt Seq.
Elect Status
Press Funct Test
Ntwks Hookup
RF Syst
Air Brg Flow
G&C Syst
Receive ST-124
Measuring Calib.
Receive LVDC
Measuring Calib.
Receive LVDA

#1.

2

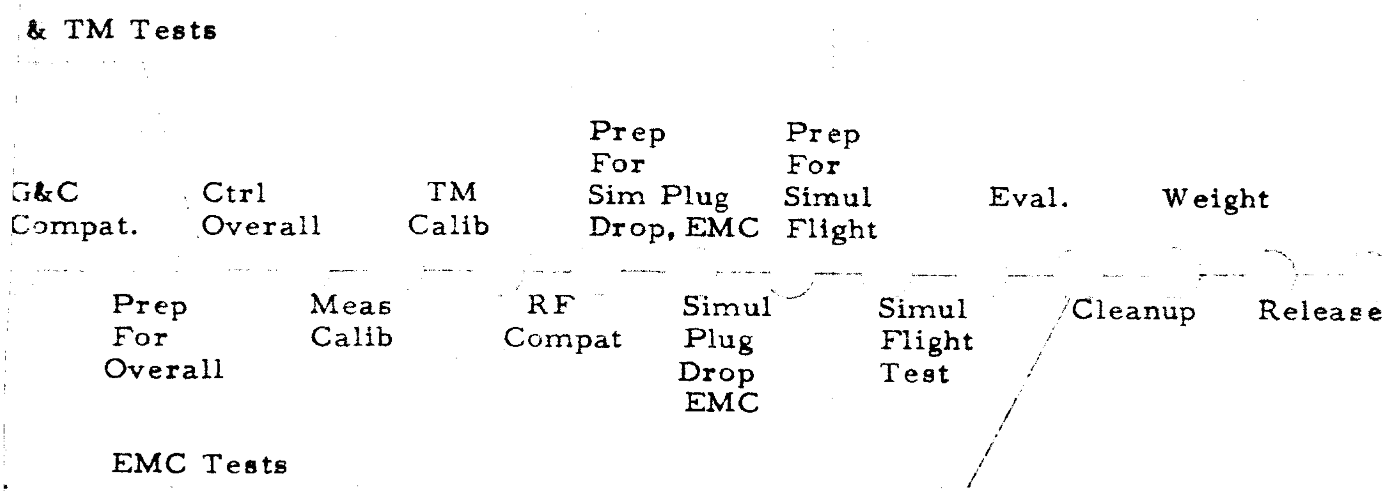


FIGURE 3-1 - Present Manufacturing Checkout, IU Stage

#2

3.0 SIMULATED FLIGHT TEST

One of the most important phases of the IU checkout will occur in the simulated flight test, the last test in the sequence of Figure 3.1. The flight profile itself will inherently include provision for checkout of the stage in orbit. In fact, for the IU and the S-IVB, a major portion of the simulated flight test presented in Figure 3.1 is a simulated orbital checkout, as expanded in Figure 3.2.

To determine what must be accomplished by post manufacturing checkout of orbital operations it is first of all necessary to establish the status of the stage in orbit. The only contact with the stage is by means of tracking stations and the R.F. links. These links must be maintained operational in order to interrogate the stage. This rules out on-off commands to check out the R.F. systems. The integrity of the R.F. systems must be determined by other means, namely, overall stage response and data quality of a satisfactory nature obtained by the ground stations. Parameters related to the R.F. systems, such as transmitter power output, will attest to the integrity of the R.F. systems. The measurement system and data acquisition system provides the strongest means of determining the status of the stage. A review of the IP&C List indicates that monitoring of 70 parameters should give a partial performance evaluation of the IU in orbit. These parameters are listed in Table 3.2.

TABLE 3.2

INSTRUMENTATION PARAMETERS

TO BE MONITORED DURING ORBITAL CHECKOUT

Parameter	Quantity
Temperature	10
Pressure	5
Vibration & Strain	5
Flight Mechanics	6
Steering Control	0*
Stabilized Platform	12
Guidance	11
R.F. & Telemetering	2
Signals	0
Misc.	0
Voltage, Current & Frequency	19
Checkout Program	(Unknown)**

* Steering controls will be monitored for the S-IVB and will include pitch and yaw positions and Delta I for pitch and yaw, 4 parameters in total.

** Before the LVDC is used for orbital checkout, a self-checkout should be performed on the LVDC, using non-destructive readout of the memory. The verification of this self-check should be accomplished by the LVDC and the ground stations.

It should be noted that no provision presently exists in the IU instrumentation for monitoring true attitude position. No provision is apparent for drift compensation in attitude measurements. Also nothing is mentioned of frequency of calibration of instrumentation channels.

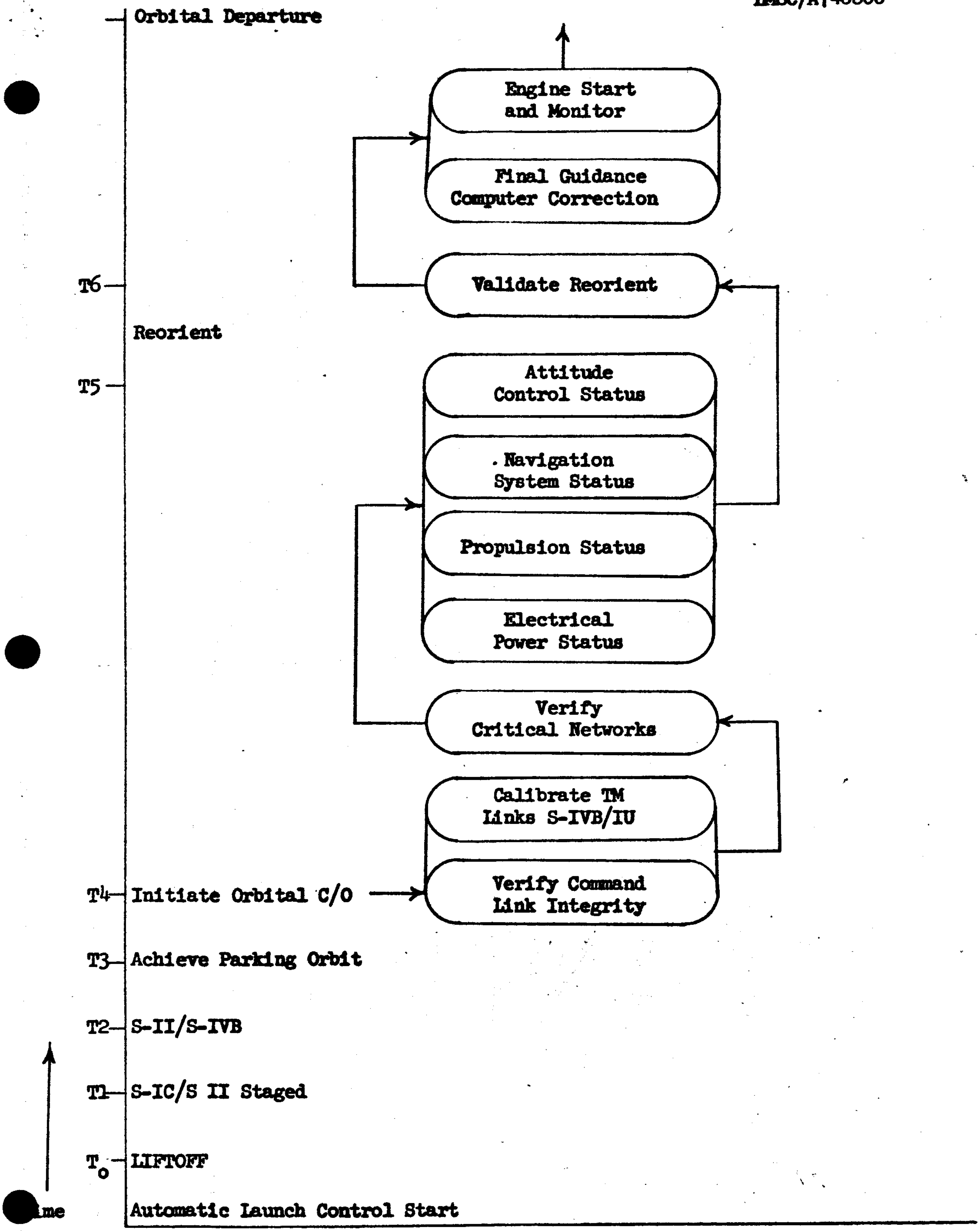


FIGURE 3.2 Simulated Flight Test (Orbital Checkout)

4.0 VEHICLE IN ORBIT STATUS

Previous paragraphs of this report have discussed various aspects of determining the status of the stage in orbit. Despite this, the question remains, does orbital checkout, as presently conceivable, accurately and sufficiently describe a vehicle ready for lunar injection? It may be noted that the use of flight control, hydraulic, and propulsion systems, etc., for orbital operations restricts the capability of exercising these systems for checkout purposes. Because of these restrictions it follows that simulation in post manufacturing checkout must give considerable emphasis to duplicating the conditions of the stage in orbit. Simulation should be as representative as possible of an orbital stage complete with fuel, oxidizer, pressurization gases, valves open and closed and control systems in the operational mode.

4.1 The Function of the LVDC in Orbital Checkout

As previously mentioned, the Launch Vehicle Digital Computer (LVDC) is not used as a part of factory checkout other than to be checked itself. For orbital checkout, the LVDC can serve in major part as the test computer. Assigned on-board checkout tests can be under computer program control. This control would exist in two categories: (1) stored programs for monitoring type of operations to be performed on a continuous cyclic basis, and (2) closed-loop tests to be conducted upon receipt of instructions via the command link from ground. It is recommended that the LVDC be a part of the test equipment for post manufacturing checkout. To do so will "close the loop" for simulation or orbital checkout, and perform the checkout most nearly in true orbital mode. Any problems related to the use of the LVDC as the orbital checkout computer will then arise and be resolved prior to launch.. For example, the computer program to control orbital checkout may be completely evaluated.

At present it is not possible to accurately define the memory storage requirements of orbital checkout operations. For the IU checkout, the 70 parameters will be in digital form, 10 bits per word. For a nominal value plus high and low values, a total of 70 x 30 or 2100 bits are required for data. It is necessary for the LVDC memory storage to also provide for orbital checkout of the S-IVB which includes 74 instrumentation parameters. This then increases the storage requirements by another 2220 bits, making a total of 4320 bits for IU and S-IVB data. This does not include the memory space necessary to store the orbital checkout program, nor the capacity required for self-checking the computer. An estimate of the programming required to process the checkout of instrument parameters would indicate the need for approximately 10 instruction words if the data was processed as one group. Breaking the checkout routine into several phases, interspersed with other computer functions would increase this to at least 20 instruction words of 13 bits each or 260 bits.

For self-checking the LVDC it is assumed that a total of 20 instructions must be exercised a minimum of 5 times each. This will require 100 words of 13 bits each, or 1300 bits. Data and constants must be stored, so assuming 50 words of 10 bits each, a total of 1300 plus 500, or 1800 bits are required for self-checking.

The total for parameter checking and self-checking requires the following storage capacity:

Instrumentation Parameters		4320
Processing Instructions		260
Self-checking		1800
	Total	6380 bits

If broad assumptions are made for priority routines, ground control commands, tape recorder control, etc., one can predict that approximately 200 additional instructions are required, or 2600 bits. The total then for orbital checkout and computer self-checking will be of the order of 10,000 bits.

In sizing the requirements of memory for the orbital checkout operation consideration must be given to the following:

a. The sequence in which instrumentation parameters for IU and S-IVB are processed, i.e., as one group, as two separate groups, or interspersed with other LVDC functions. It is estimated that approximately 7 milliseconds will be required to self-check the LVDC and to check out the IU and S-IVB in orbit. Even with a safety factor of two applied to this estimate, 14ms represents a short period of time relative to the contact time with a tracking station. Hence, it appears unnecessary to split the orbital checkout into subgroups other than to self-check the LVDC prior to other checkout.

b. Program instructions for switching between automatic cyclic checkouts conducted by the LVDC, and ground commanded routines directed to the computer.

c. Program instructions for switching between tape recorder operations during orbital blind spots and direct transmission of checkout data to ground stations.

d. Memory capacity requirements for self-checking the LVDC.

e. Storage requirements for the instrumentation parameters including high and low values.

f. Interrupt or priority requirements related to ground commands, or to checkout parameters found to be critical values by the LVDC.

g. Potential use of a portion of the LVDC as a simulator of vehicle rigid body attitude dynamics for use in assessing response and recovery of the attitude and control system in the presence of attitude disturbances. This concept, which may possibly be as shown in Figure 3.3 will be analyzed in Phase II of the study to assess its feasibility and to determine memory storage requirements. References d through j in the Bibliography (Appendix 1) contain information on this topic.

The present memory capacity of the LVDC is 36,768 words of 26 bits each. Since it is not known what storage capacity is required for pre-launch checkout, launch operations and the flight profile it cannot be determined what affect the orbital checkout has on memory capacity. However, it does not appear to be severe from this initial analysis. If additional checkout tests were to be devised they might overrun this conclusion as well as having significant affect on basic stage hardware. This area of study will be expanded in Phase II of the study.

4.2 Tape Recorder Operation

The tape recorder is usually used in orbital flights to store instrumentation data during blind spots when the vehicle is out of reach of tracking stations. For Saturn V flights with the IU and S-IVB in orbit, the tape recorder could be used in two modes. The first would be to store data during orbital blind spots. The second mode, a recommendation of this technical note, would be to store checkout parameter "NO-GO's", as generated by the LVDC, instead of storing the actual value of the parameter itself. This would maximize the storage capacity of the tape recorder, would minimize the amount of data to

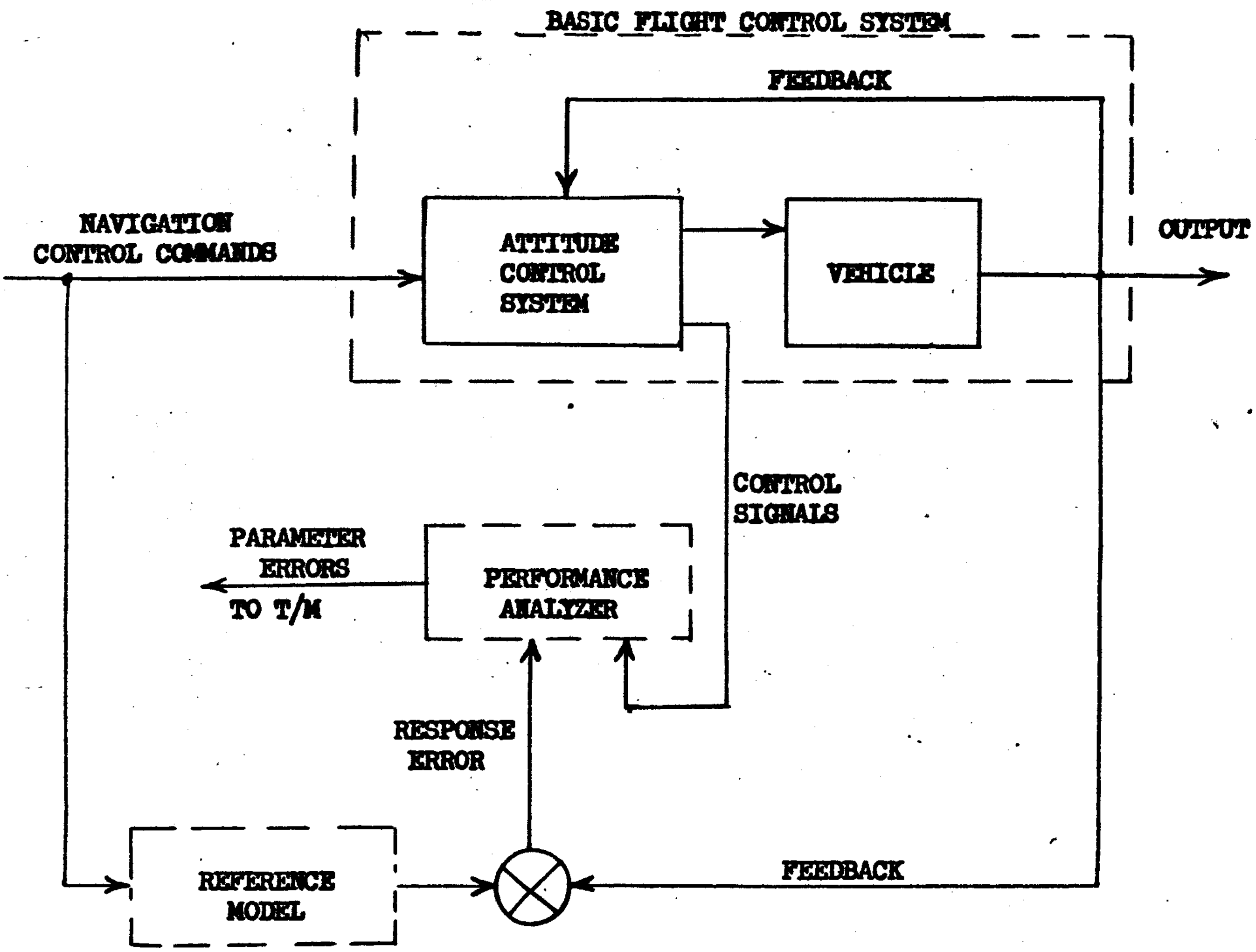


FIGURE 3.3 Simplified Block Diagram of a Model Reference Adaptive Flight Control System

be transmitted to a tracking station and would reduce the ground time required to evaluate the performance of the orbiting vehicle. Most space-application tape recorders have 20 to 30 minute recorder capability, with a playback at 4 times recording speed. For $4\frac{1}{2}$ orbits, tracking station contact time is estimated to be a total of 20% or about 80 minutes. This reduces to be approximately 20 minutes of time per orbit, leaving 70 minutes of blind time per orbit. If one assumes 3 stations may contact the vehicle per orbit, 23 minutes of blind time will exist between stations. This is compatible with 30 minutes of recording time, and 5 to 7 minutes of station contact time for playback.

A review of the characteristics of the ascent tape recorder in the IU indicates that an analog type is used and it has a recording time of 180 seconds. This is insufficient for the blind spots of orbital flights. A digital recorder with at least 30 minutes of recording time will be required for orbital checkout.

5.0 PROBLEM AREAS IN SIMULATION OF ORBITAL CHECKOUT

5.1 Simulating Orbital Environmental Conditions

a. Zero g conditions - A stage in orbital operation will be experiencing zero g conditions, thereby posing the question of how does one simulate zero g in post manufacturing checkout area, or perhaps, does the zero g condition need to be simulated. Along these lines is the question of how to simulate operational checkout of accelerometers in such an environment. Post manufacturing checkout for accelerometer operation should provide a means of orienting the platform and accelerometers, one axis at a time, in order to check the other axes at equivalent zero g on sensitive axes. Alternately the outputs of the accelerometers should be accessible to checkout test equipment so that a 1-g value could be subtracted in order to simulate zero g conditions. A combination of both approaches may be desirable. In either case the standard trajectory computations stored in the LVDC for checkout will need to differ in significant aspects from those stored for orbital operations.

b. Horizon Sensor Operation - During orbital operations the horizon sensors will be detecting infrared energy from the earth's surface. Laboratory type of equipment may be used in post manufacturing checkout to verify proper operation of the horizon sensors. Horizon sensors of the future may be provided (for Saturn V) with thin wires or other thermal referents for checking out the sensors during orbit. Their potential use to validate platform indications generates additional problems in the simulation.

c. Attitude Positions - The stage in orbit will assume an attitude position as prescribed by the mission profile. In addition, limit cycling will occur which the LVDC and platform must deal with. This raises the problem of simulating the attitude position statically and dynamically during post manufacturing checkout. Provisions should be made to drive the platform with the gyros free so that attitude positions and rates can be simulated, and more precise in situ checks made of platform and autopilot loop instrument channel accuracies.

d. Reactions from S-IVB Venting Cycles - The S-IVB is vented at various times during orbital operations, and will produce minor accelerations as a result. The acceleration due to venting is calculated to be 10^{-3} g and is directed along the thrust line of the vehicle. It may be determined (at a future date) that these reactions are sufficiently small so as to be ignored during orbital checkout. If this should be true it would be unnecessary to simulate the reactions during post manufacturing checkout.

e. The total closed loop simulation of these several features in the factory environment imposes peculiar constraints on both the LVDC and checkout ESE.

6.0 POST MANUFACTURING CHECKOUT OF THE IU WITHOUT THE S-IVB

It has been discussed that simulation should represent the orbital stage as nearly as possible. It is highly probable that the IU will undergo factory checkout without the S-IVB. It is recommended that the IU be mated with the S-IVB for post manufacturing checkout tests. The IU is the control center for all of the stages of the Saturn V after liftoff takes place. In order to fully evaluate the functional compatibility of the IU and the S-IVB it is highly desirable that the checkout of these stages take place under mated conditions. No better simulation can be provided than the use of the actual stage itself.

CHAPTER 4

A STUDY OF REQUIREMENTS TO HAVE FLIGHT IU MATED WITH S-IVB FOR FACTORY CHECKOUT

1.0 INTRODUCTION

Chapters 2 and 3 contain recommendations that the flight IU stage be mated to the S-IVB stage prior to final factory checkout of both stages. These were based on the development of a plan for factory checkout of the S-IVB which included the following requirements:

- o Use of the IU DDAS system for transmission of S-IVB parameters to be used in orbital checkout.
- o Use of the LVDC for on line checkout, decision making and control of the orbiting stages and/or data compression prior to transmission of data to ground control.
- o Conducting the factory checkout simulation of orbital checkout between firings of a multiple firing static test.

In part, the recommendations state that "In order to fully evaluate the functional compatibility of the IU and the S-IVB it is highly desirable that manufacturing checkout of these stages take place under mated conditions. No better simulation can be provided than the use of the actual stage itself".

This chapter is a study made to determine the desirability of the IU/S-IVB mating for factory checkout under the assumption that only the first of the conditions listed above is to be implemented, to weigh the gains to be made from this procedure against the penalties involved, and to make an appropriate recommendation on this problem.

2.0 CONCLUSIONS

The recommendation to mate the IU and the S-IVB during manufacturing checkout is valid under the limitations given in paragraph 1.0 of this chapter. However, the benefits to be derived therefrom may be overshadowed by logistics and scheduling problems.

The characteristics of the signals and voltage levels which pass through the IU/S-IVB interface, with exception of the DDAS train, are such that electrical simulation for IU checkout may be rather easily accomplished in an S-IVB substitute unit. Mechanical functions, such as valve operations, may be simulated by relay operations with suitable time delays for feedback signals to verify that the commanded events have taken place. In the case of engine actuators, either prototypes or flight components could be used in the stage substitute or the substitute could include an electrical analog so that standard responses to commands may be obtained for loop checks.

A large penalty in using a stage substitute will be the inability to evaluate the electromagnetic compatibility of the actual stages. An additional penalty will be the absence of true data transfer from the S-IVB to the IU for checkout. It is recognized that the latter penalty may be lessened by using a paper tape program in the stage substitute to simulate data transfer from the S-IVB to the IU. Nevertheless, the use of an S-IVB substitute unit in manufacturing checkout will not be representative of orbital conditions.

With the exception of the DDAS link, requirements for simulation of IU functions for S-IVB checkout are not so extensive as to warrant use of the IU instead of special test equipment. However, the DDAS link to the IU requires simulation of the dynamic impedance of the link termination in the IU. The termination must be capable of providing a range of noise content, IU digital multiplexer reference voltage level variations and synchronization perturbations which will permit assuring successful operation of S-IVB DDAS telemetry in the face of such disturbances. And, of course, the reverse problem exists in assuring that the IU telemetry system can tolerate perturbations arising from S-IVB DDAS variations. Since the nature and severity of such problems has historically been highly sensitive to electromagnetic transmission paths which involve the structure and equipment arrangements, electrical simulation of the normal DDAS transmissions in the IU would not appear to be adequate for S-IVB checkout. Nor would strictly functional simulation of S-IVB DDAS source impedance and signal content be satisfactory for IU checkout. For these reasons physical mating of the S-IVB and IU during factory checkout appears to be necessary.

There is an alternate course however. This involves use of a physical and functional mockup of the S-IVB for IU check, and IU mockup for S-IVB check. The S-IVB mockup would be similar to the one presently used by Douglas at Huntington Beach, California. This would overcome most of the objections cited for use of a stage substitute. Admittedly the mockup would not be identical to the S-IVB in every respect, but it would be more nearly representative of actual stage conditions than a stage substitute unit. A mockup of the S-IVB would permit IU manufacturing checkout to include evaluation of the LVDC capability to perform orbital checkout, which might be difficult with the use of an electrical stage substitute unit.

Both IU and S-IVB mockups would be subject to rigid configuration control. Equipment installed in them would be replaced periodically to assure continued standard performance and to permit necessary refurbishing and updating. More than one set of critical functional equipment would need to be assigned to such a program to maintain adequate resupply levels for normal rotation and replacement of faulty equipment.

3.0 ANALYSIS

It is assumed that the transfer of DDAS data from the S-IVB to IU will be accomplished through either the Remote Digital Multiplexer or Remote Digital Submultiplexer in the IU. Interleaving of this input with other digital data obtained from the IU will require some modicum of synchronization between the two systems or else a separate buffer to accomplish the same ends. From the digital multiplexers in the IU the data will be forwarded to IU DDAS assembly for transmission of the IU PCM Telemetry or selected input to the LVDA for orbital checkout processing. In the latter instance control of the DDAS is accomplished through the IU Computer Interface Unit under control from the LVDA, in turn under control of the LVDC via PIO lines.

3.1 CHECKOUT OF THE I.U.

Recommendations for manufacturing checkout of the IU were reviewed and the following items were analyzed in order to evaluate the recommendation regarding mating of the S-IVB and IU:

1. Electrical Interface for IU/S-IVB
2. Electrical Simulation Requirements
3. S-IVB Data Transfer to the LVDC
4. EMI Compatability
5. Alternate Recommendation - an S-IVB Mockup
6. Logistics

Of the five connectors which form the interface, essentially only two are dynamically related to the S-IVB. The other three connectors are assigned to S-IC and S-II functions, except pins q and r of connector No.3. These pins carry the S-IVB vent cycle start and stop request to the LVDC. The functions which pass through the electrical interface are:

Switch Selector Operations

Engine Actuator Commands

Engine Cutoff Commands

Engine Out Signals

Actuator Position Measurements

Attitude Control Commands

Rate Gyro Outputs

Accelerometer Outputs

Vent Cycle Start/Stop Commands

Separation Signals

Timing Functions

DC Returns

Connector Confidence Loops

Shield Connections

3.1.1 Electrical Simulation Requirements

The voltage levels for signals, commands and measurements through the interface are 0-5 vdc, 0-10 vdc, plus 28 vdc, or minus 28 vdc. The characteristics of these functions (pulses, levels, etc.) may be duplicated by rather common circuitry and logic. Timing and control of circuits in the stage substitute unit can be provided by the Launch Control Computer. Line and load terminations must be provided to represent relays, valve coils, actuators, and other components in the S-IVB.

3.1.2 S-IVB Data Transfer to IU

During orbital checkout, data from the S-IVB DDAS will be transferred to the IU via the Remote Digital Multiplexer, or Remote Digital Submultiplexer in the IU. For manufacturing checkout of the IU the stage substitute for the S-IVB must include provisions for this data transfer. Since present checkout procedures for the IU are not concerned with this data transfer, further study must be devoted to analyzing the Stage Interface Test Set, (SITS). Documentation related to SITS is not available at LMSC at this writing. It is assumed that SITS does not generate data comparable to S-IVB measurements. It is possible that a tape reader may be added to SITS to process tapes punched with S-IVB parameters. The tapes could be changed to include variations in parameters to simulate No-Go conditions. If SITS, or some similar stage substitute, does not provide for data transfer from the S-IVB to the IU it will not be possible to evaluate the LVDC's ability to control orbital checkout.

3.1.3 EMI Compatibility

The use of a stage substitute unit instead of the S-IVB precludes the ability to check the IU and S-IVB for EMI compatibility prior to assembly at Kennedy Space Center. Problems for this category can be of major impact, influenced as they may be by minor differences between IU and S-IVB as regards to frame rate, reference voltage levels, noise content and electromagnetic transmission paths through structure as well as wires.

3.1.4 Alternate Recommendations: An S-IVB Mockup

An alternate approach to manufacturing checkout of the IU without the S-IVB is to use a mockup of the S-IVB This would be similar to the mockup at Douglas in Huntington Beach. Flight type components would be used in a configuration representative of cable wiring in the S-IVB. Components not included in the mockup, such as the engine, would be simulated by black boxes to accept input signals and generate suitable outputs. The mockup would provide actual line and load terminations by the use of flight components instead of dummy loads as in a stage substitute. The cable and harness routing would provide a rather accurate representation of stage wiring and would facilitate EMI evaluation.

3.1.5 Logistics

The three concepts considered in this analysis, namely, a stage substitute unit, a mockup, and mated stages represent increasingly difficult logistics problems in the order listed.

3.2 CHECKOUT OF S-IVB

In the absence of mechanical interface problems the desirability of mating the IU with the S-IVB during factory checkout is a function of the problems of simulation of the electrical interface encountered by not operating in this fashion. The S-IVB/IU electrical interface is composed of five connectors, four of which for the most part have identical connectors at the S-IVB/S-II interface to send the signals to the lower stages. The basic problem in checkout of these connectors and interconnecting cables can be divided into two parts, determination of the electrical integrity of the equipment and the determination of whether problems exist due to noise induced by the dynamic operation and loading of the lines. The first part of this problem is easily met by impedance testing and insulation tests. The second half of the problem is more difficult because varying line loadings and impedance termination must be simulated. The problem of achieving the necessary simulation in the absence of the IU will be the only part of the checkout discussed. In addition the problem of signal simulation for those stimuli controlling the S-IVB will be examined.

3.2.1 Interstage Connector No. 5

Interstage Connector No. 5 covers only S-IVB parameters. These are:

Main engine pitch and yaw command

Main engine pitch and yaw feedback signals

Attitude control commands

S-IVB control gyro and accelerometer signals

The signals carried on these lines can be divided into four general categories: (1) discrete step signals between 0 and 200 milliamperes associated with the operation of the S-IVB attitude control nozzles, (2) analogue command signals of 50 milliamperes peak associated with the main engine controls, (3) analogue sense signals of 50 microamperes peak associated with engine control feedback signals, and (4) analogue sense signals of approximately 200 microamperes maximum which are the control gyro and accelerometer outputs. The test objective for dynamic checkout of these lines is to determine if any unwanted signals occur when the lines are terminated in their proper impedance and are operating in normal modes. These requirements are easily achieved without the presence of the IU, by proper choice of terminating impedances and voltage sources for the lines. Use of a Control Computer or Control Computer Simulator will suffice for this purpose. Appropriate command generation and return signal sensing for both normal and noise content can be obtained straightforwardly without recourse to special test equipment other than the Control Computer Simulator.

3.2.2 Interstage Connector No. 4

Interstage Connector No. 4 carries lines connected with the switch selector. There are 26 lines passing through the S-IVB to the lower stages. Twenty-two of these lines have T's going to the S-IVB switch selector and two of each of the remaining terminate in the S-II and S-IC stage. In addition there are two switch select lines terminating in the S-IVB switch selector. These lines carry only 28 volt on/off type signals. Loads vary from 100 to 1000 ohms. The stage select lines are continuously terminated, provided the stage is present, but the remainder are unterminated unless one or more stages have been selected. Operational checkout of the S-IVB stage selector can be adequately accomplished without the presence of the IU. Noise does not appear to be a factor in any of the circuits except for the possibility of the generation of a large enough spike on a stage select line to latch the associated relay. No problems will be encountered in evaluation of this possibility if the IU is not present. Generation of noise on the lines of connector No. 5 by actions on the lines of connector No. 4 can also be evaluated without an IU being present, provided adequate simulation of the Control Computer is provided on the lines of connector No. 5.

3.2.3 Interstage Connector No.3

Interstage Connector No. 3 between the IU and S-IVB in general carries signals applicable only to S-II and S-IC. The exceptions are lines carrying S-IVB 28 V power to the IU for timing purposes, a line carrying 28 V from the IU to the S-IVB for similar purpose, a line from the S-IVB to the LVDC carrying Ullage rocket firing and vent request and a line carrying the S-IVB engine cut-off command. The remaining functions at the S-IVB/IU interface are analogue signals representing outputs of the S-II control gyro and accelerometers, S-IC and S-II engine cut-off signals, S-IC and S-II engine out signals, and S-IC and S-II aft skirt separation signals.

All of the signals terminating in the S-IVB are 28 V level discrete signals. Signal simulation can be achieved by simple relay closures. Noise effects on the analogue lines coming through from the S-II can be evaluated at the same time, and also any of the lines carrying discrete from the other stages can be evaluated. The effect of absence of the IU in these checks will be negligible.

3.2.4 <u>Interface Connector No. 2</u>

Interface Connector No. 2 contains only 5 volt feedback lines from the IU to the S-II and S-IC engine actuators and the associated return. No lines terminate at or are attached to any S-IVB equipment. Evaluation of noise on these lines can be checked with suitable termination made at the interface plugs and readouts of noise induced on the lines by S-IVB equipment operation. No IU will be required for these circuits.

3.2.5 <u>Interface Connector No. 1</u>

Interface Connector No. 1 carries 5 V analogue command signals for the S-II and S-IC stages. There are no terminations in S-IVB. The problem associated with checkout of these circuits is similar to that of circuits associated with Connector No. 2.

3.2.6 <u>DDAS Link</u>

Transmission of DDAS data from the S-IVB to the IU requires extensive and detailed simulation to assure that in-tolerance conditions on the IU terminations for the transmission line will not impair data transfer or the performance of S-IVB telemetry, or that a reasonable class of faults on the termination will not disable the S-IVB telemetry. The simulation will be of dubious value if electromagnetic transmission through the interface structure or radiation through normal intervening space is precluded.

4.0 <u>CONCLUSION</u>

Mating of the IU and S-IVB for factory checkout is desirable to permit certification of the electromagnetic compatibility of the S-IVB and IU when the two are coupled by transmission of DDAS data from the S-IVB to the IU. Stronger arguments exist for such mating if the IU is to carry out computations of residual propellants on board for second start.

An acceptable alternate to this is the assignment of one or more controlled IU mockups to factory checkout of the S-IVB. The mockups, or at least their critical assemblies, would be rotated between IBM and Douglas periodically for necessary updating and refurbishing. This practice is quite analogous to that currently followed in the Polaris Program.

CHAPTER 5

REVIEW OF SPACE VEHICLE STAGE ANALYSIS AND CHECKOUT GUIDELINES

SR-QUAL-64-13, "Space Vehicle Stage Analysis and Checkout Guidelines" Section 7.10.3 was reviewed to identify those items which are compatible with a stage which is fueled, pressurized and inaccessible on orbit - except through R. F. link, and those which are highly desirable even though incompatible with this configuration. The number of items that are compatible are limited due primarily to the fact that during coast the stage systems are essentially in a static condition which should not be changed until second burn is initiated. Most of the components and subsystems that could be exercised for checkout without upsetting the status of the stage are controlled by sequencers which would also exercise components or subsystems which would upset the status of the stage.

The number of incompatible items that are considered highly desirable are limited because the supply of electrical power and pressurants is limited and not replaceable. Under these limitations it is generally felt that it is better in most instances to determine the conditions of the systems from information obtained during first burn and monitoring them in static condition rather than using the expendables to exercise them.

If more electrical power and pressurants were on board and if more of the components and subsystems could be exercised independently, the results of the analysis may be considerably different.

TABLE 5

SR-QUAL-64-13, SECTION 7.10.3 AUDIT

Y = Yes
N = No
P = Partly
NA = Not Applicable

Paragraph	Compatible	Desirable	Comments
1.2			Power Distribution
a.	N	N	No GSE - Stage connections
b.	N	Y	Proper buss voltage would indicate but not positively assure correct connection and buss resistance.
c.	P	Y	Complete sequencing could not be performed since voltage should not be applied to all networks, circuits and components of a stage in this configuration. Buss current would give indication of correct load for the configuration at time of measurement.
d.	P	Y	Same as c.
e.	N	P	Will not be possible to disconnect from the busses subsystems not being checked out.
f.	N	Y	Independence of busses cannot be positively determined. Buss current measurement would give reasonable assurance.
2.2			DDAS
a.	Y	Y	
b.	N	N	Not possible to disconnect signal cables.
c.	N	P	Onboard "hi-lo" calibrate signals can be used to check this.
3.2			Pressure and Functional Tests
a.	NA	NA	No connections will be disconnected.
b.	NA	NA	No leak test solutions will be used.
c.	NA	NA	Same as b.
d.	NA	NA	No covers will be removed.
e.	NA	NA	Same as a.
f.	NA	NA	Systems are already pressurized. No pressurization source available.
g.	NA	NA	No means of detecting audible leakage.
h.	N	N	Pressure "drop-off" is the only tests possible.

TABLE 5 (Cont'd)

Y = Yes
N = No
P = Partly
NA = Not Applicable

Paragraph	Compatible	Desirable	Comments
3.2 (Cont'd)			
i.	P	Y	Pressure "drop-off" tests can be performed on the pressurized systems except possibly the attitude control subsystem which will be active during the coast period. Some results may be meaningless for the propellant tankage where both boiloff and venting may be occurring.
j.	N	N	Same as f.
k.	N	N	Same as g.
l.	N	N	Same as f.
m.	NA	NA	Repairs not planned.
n.	N	N	Tracer gases will not be used.
o.	NA	NA	No systems will be "opened".
p.	N	N	
q.	N	N	
r.	NA	NA	Systems pressure will not be increased during tests.
s.	P	Y	This will apply to flight gages and transducers. No others will be used.
3.3			AC Heaters
3.3.2			
a.	N	N	
b.	N	N	
c.	N	N	Units will cycle automatically to maintain set temperature.
d.	N	N	Current not monitored.
3.4.2			Pressure Switches
a.	N	N	Systems will be static and cannot be cycled or pressurized.
b.	N	N	Same as a.
c.	N	N	Same as a.
d.	N	N	Same as a.
e.	N	N	Same as a.
f.	N	N	Same as a.
g.	N	P	Probably can only be done by monitoring pressure drop on pressurized systems.

TABLE 5 (Cont'd)

Y = Yes
N = No
P = Partly
NA = Not Applicable

Paragraph	Compatible	Desirable	Comments
3.5.2			Control Pressure System
a. thru h.	N	N	Systems are pressurized and/or static and cannot be cycled.
3.6.2			Gas Generator Oxidizer and Fuel Control Valve Assemblies
a. thru f.	N	N	System cannot be exercised to test.
3.7.2			Gas Generator, Gas Turbine, Turbine Exhaust and Turbopump Gearcase Test
a. thru e.	N	N	Test not compatible with static system status.
3.8.2			Engine Control Systems Tests
a. thru f.	N	N	Test not compatible with static system status.
3.9.2			Oxidizer Pressurization System
a.	N	P	Pressure "drop-off" measurement on pressure container is only test possible.
b.	N	N	
3.10.2			Engine Purge System
a.	N	P	Pressure "drop-off" measurement on storage equipment can be made.
b. & c.	N	N	
3.11.2			Propellant Utilization
a., b., & c.	N	N	
3.12.2			Oxidizer Tank and Combustion Chamber Test
a. thru g.	N	N	
3.13.2			High Pressure Spheres and Fuel Tanks
a. thru h.	N	N	
i.	P	P	Pressure "drop-off" of high pressure spheres can be measured.
3.14.2			Hydraulic Systems
a. thru e.	N	N	
f.	Y	Y	
g. & h.	N	N	

TABLE 5 (Cont'd)

Y = Yes
N = No
P = Partly
NA = Not Applicable

Paragraph	Compatible	Desirable	Comments
3.15.2			Instrument Canister and Cooling System
a. thru f.	N	N	Proper operation of system will be indicated by proper temperatures.
4.2			General Network and Malfunction Tests
a. thru e.	N	N	
f.	P	Y	Properly received commands can be verified.
g. thru j.	N	N	
5.2			Measuring Subsystem
a.	P	Y	Some of these measurements cannot be made due to inability to exercise the subsystems.
b.	P	Y	Outputs can be returned to DDAS ground station via telemetry for comparison with predicted values.
c.	P	Y	
d.	P	P	Can be accomplished only to the extent of onboard calibration signals. Environment cannot be changed.
e.	P	P	Systems generally cannot be operated. Measurements on static systems will give some information.
f.	Y	Y	
6.2			Telemetry Systems
a.	N	N	
b.	P	P	Can be checked only to the extent that it can be determined from signals received at the ground station.
c.	P	P	Same as b.
d.	N	N	
7.2			R.F. Systems
a. thru d.	N	N	
e.	P	P	Transponders will be energized by output of transducers and signal conditioners. Input frequencies will not be known.
f. & g.	N	N	

TABLE 5 (Cont'd)

Y = Yes
N = No
P = Partly
NA = Not Applicable

Paragraph	Compatible	Desirable	Comments
8.1.2			Engine Gimballing System
a.	Y	Y	
b.	P	P	Movement cannot be observed. Position potentiometers output will give indications.
c.	P	Y	Can be done to the extent of onboard transducers to monitor these parameters.
8.2.2			Rate Gyro Assembly Tests
a. thru d.	N	N	
8.3.2			Control Accelerometer Tests
a. b. & c.	N	N	
8.4.2			Auxiliary Control System Assemblies
a. b. & c.	N	N	Proper orientation of stage during coast will give indication of proper functioning.
9.2			Steering Overall Tests
a. thru g.	N	N	First burn performance and gimballing test of Paragraph 8.1.2 would provide useful information.
10.2			R.F. Compatibility Test
a. thru d.	P	P	Systems will be in an operating condition. Not all systems can be operated and sequence will be determined by orbital coast monitoring requirements. Interaction must be evaluated from signals received on ground.
11.2			Electro Magnetic Compatibility (EMC) Test
a.	Y	Y	Possible if ground stations have monitoring equipment. Signal level may be too low to detect on ground.
b.	N	N	
c.	Y	Y	

TABLE 5 (Cont'd)

Y = Yes
N = No
P = Partly
NA = Not Applicable

Paragraph	Compatible	Desirable	Comments
11.2 (Cont'd)			
d.	Y	Y	
e.	N	N	
f.	Y	Y	
g.	P	P	May not be possible to monitor the individual systems that are extremely susceptible.
h.	P	P	
i.	N	N	
j.	N	N	
k.	N	N	
l.	N	N	
12.2			Instrumentation Compatibility Test
a.	P	P	Telemeter system output for those channels being monitored can be recorded and onboard calibration signals can be used.
b.	P	P	
c.	P	P	Same as a.
d.	N	N	
e.	P	P	
f.	Y	Y	
13.2.2			Simulated Plug Drop Test
a. thru i.	N	N	
13.3			Plug Drop
a. thru f.	N	N	

APPENDIX 1

BIBLIOGRAPHY

a. LMSC Technical Note, Contract NAS 8-11477, "Manufacturing Checkout of Orbital and Operational Stage - Introduction to the Study" dated 23 November 1964

b. Douglas Aircraft Company, Report #SM-46695, "Orbital Checkout of S-IV-B" dated 27 May 1964

c. Marshall Space Flight Center SR-QUAL-64-13, "Space Vehicle Stage Analysis and Checkout Guidelines" dated 1 May 1964

d. IP&C List, Instrument Unit, S-IU-9, MSFC 50M10376, dated March 12, 1963

e. Launch Vehicle Digital Computer, TMR Prototype Model, Design and Performance for IBM 6109007

f. Launch Vehicle Data Adapter, Redundant Prototype Model, Design and Performance For, (IBM Preliminary copy)

g. Whitaker, H. P., "Use of Model-Reference Adaptive Control to Achieve a Specified Performance", Report MIT-IL-R407, April 1963

h. Electrotechnology Science and Engineering Series:

   1. Eveleigh, V. W., "Adaptive Control Systems", April 1963, page 86
   2. Skinners, S. M., "Optimal and Adaptive Control Systems", July 1964, page 75

i. Sepahban, A. H., Podraza, A., "Digital Implementation of Time Optimal Attitude Control", 1963 Joint Automatic Control Conference, June 1963, page 532

j. Instrumentation Unit Model Specification Saturn 1-B/V Launch Vehicle, MSFC-CD-214-506, Review Draft dated July 1, 1964

ORBITAL CHECKOUT PARAMETERS FOR IU-9
(EXTRACTED FROM IP&C LIST, IU-9)

MEASUREMENT NO./TYPE	NAME/OR COMPONENT	RANGE	% POS ERROR	T/M CHANNEL	RESP.	FLT. CALIB.
TEMP:						
C123-802	AIR BEARING SUPPLY ST-124	25 ± 5°C	05	F6-X-B14-10 P1B2-14-10	2.4	YES
C174-802	GUIDANCE COMPUTER	10-75°C	05	F6-X-B14-03 P182-14-03	2.4	YES
C175-802	GUID. SIG. PROCESSOR	10-120°C	05	F6-X-B14-04 P1B2-14-04	2.4	YES
C309-802	INERTIAL GIMBAL ST-124	35-55°C	05	F6-X-B04-01 P1B2-04-01	2.4	YES
C315-802	BATTERY 1 INTERNAL	0-70°C	05	F6-X-B12-05 P1B2-12-05	2.4	YES
C316-802	BATTERY 2 INTERNAL	0-70°C	05	F6-X-B12-06 P1B2-12-06	2.4	YES
C319-802	IU AMBIENT #1	-10-30°C	05	P1B1-12-06	2.4	YES
C320-802	IU AMBIENT #2	-10-30°C	05	P1B1-12-07	2.4	YES
C321-802	IU AMBIENT #3	-10-30°C	05	P1B1-12-08	2.4	YES
C322-802	IU AMBIENT #4	-10-30°C	05	P1B1-12-09	2.4	YES
PRESSURE:						
D74-802	AIR BRG SUPPLY ST-124	0-3500 PSIA	05	P1B1-12-02	2.4	YES
D89-802	AIR BRG SUPPLY ST-124	0-60 PSID	05	F6-X-B14-06 P1B2-14-06	2.4	YES
D169-802	INTERNAL AMBIENT ST-124	0-20 PSIA	05	P1B1-08-02	2.4	YES
D191-802	CONTROL SIG. PROC.	0-25 PSIA	05	F6-X-B15-04 P1B2-15-04	2.4	YES

ORBITAL CHECKOUT PARAMETERS FOR IU-9
(EXTRACTED FROM IP&C LIST, IU-9)

MEASUREMENT NO./TYPE	NAME/OR COMPONENT	RANGE	% POS ERROR	T/M CHANNEL	RESP.	FLT. CALIB.
PRESSURE:						
D192-802	CONTROL COMPUTER	0-25-PSIA	05	F6-X-B15-05 P1B2-15-05	2.4	YES
VIBRATION:						
E90-802	X AXIS INER. GMBL ST-124	± 5G	10	S3-01E01	3KC	YES
E91-802	Y AXIS INER. GMBL ST-124	± 5G	10	S3-02E01	3KC	YES
E92-802	Z AXIS INER. GMBL ST-124	± 5G	10	S3 03E01	3KC	YES
E357-802	BENDING, VIB PITCH	± 0.5G	10	F6-X-B11 P1B2-11	25	YES
E358-802	BENDING, VIB YAW	± 0.5G	10	F6-X-B13 P1B2-13	25	YES
FLIGHT MECH:						
F40-802	ACCEL. PITCH CONTROL	± 5 M/SEC^2	03	F5-03 P1B1-05-01	11	YES
F41-802	ACCEL. YAW CONTROL	± 5 M/SEC^2	03	F5-17M02 P1B1-05-02	8	YES
F42-802	ANG. VEL PITCH CONTROL	± 10 °/SEC	05	F6-08 P1B1-07-05	45	YES
F43-802	ANG. VEL YAW CONTROL	± 10°/SEC	05	F6-05 P1B1-05-04	20	YES

ORBITAL CHECKOUT PARAMETERS FOR IU-9
(EXTRACTED FROM IP&C LIST, IU-9)

MEASUREMENT NO./TYPE	NAME/OR COMPONENT	RANGE	% POS ERROR	T/M CHANNEL	RESP	FLT CALIB.
FLIGHT MECH:						
F44-802	ANG. VEL ROLL CONTROL	$\pm$ 10°/SEC	05	F6-04 P1B1-05-05	14	YES
F55-802	CONTROL ACCEL SWITCH	OFF-ON		P1B1-09	25	YES
STBL PLATFORM:						
H17-802	Y GYRO PICKUP, ST-124	$\pm$ 1°	05	P1B1-14 F6-11	110	YES
H18-802	Z GYRO PICKUP, ST-124	$\pm$ 1°	05	F6-12 P1B1-15	160	YES
H19-802	X GYRO PICKUP, ST-124	$\pm$ 1°	05	F5-12 P1B1-19	160	YES
H20-802	REDUNDANT SERVO SIG ST-124	$\pm$ 3°	05	F6-14 M03 P1B1-21	11	YES
H21-802	ALTITUDE ACCLR PICKUP, ST-124	$\pm$ 1°	05	F5-13 P1B1-23	220	YES
H23-802	C.R. ACCLR PICKUP, ST-124	$\pm$ 1°	05	F5-11 P1B1-24	110	YES
H24-802	ATTITUDE, ROLL ST-124	$\pm$ 15°	05	F6-X-B15-01 P1B2-15-01	2.4	YES
H25-802	ATTITUDE, YAW ST-124	$\pm$ 15°	05	F6-X-B15-02 P1B2-15-02	2.4	YES
H26-802	ATTITUDE, PITCH ST-124	$\pm$ 15°	05	F6-X-B15-03 P1B2-15-03	2.4	YES
H40-802	ATTITUDE, ROLL ST-124	$\pm$ 2.5°	05	F5-17M03 P1B1-04-05	11	YES
H41-802	ATTITUDE, YAW ST-124	$\pm$ 2.5°	05	F5-14M02 P1B1-04-06	8	YES

ORBITAL CHECKOUT PARAMETERS FOR IU-9
(EXTRACTED FROM IP&C LIST, IU-9)

MEASUREMENT NO./TYPE	NAME/OR COMPONENT	RANGE	% POS ERROR	T/M CHANNEL	RESP	FLT CALIB
STBL PLATFORM:						
H42-802	ATTITUDE, PITCH ST-124	$\pm 2.5^{\circ}$	05	F6-06 P1B1-04-07	25	YES
GUIDANCE:						
I8-802	GUID COMPUTER OPERATION			P1B2-09,10 P1B1-10,11	DIG	NO
I14-802	1.8KC VOLTAGE, GSP	0-30V	05	F6-X-B01-09 P1B2-01-09	2.4	YES
I15-802	1.5KC VOLTAGE, GSP	0-30V	05	F6-X-B-01-10 P1B2-01-10	2.4	YES
I16-802	COMMAND SYSTEM DECODER		10	P1B1-12-01	DIG	NO
I4-802	VELOCITY ALTITUDE, ST-124	0.1M/SEC/PULSE	05	F5-16 P1B1-05-07	600	NO
I6-802	VELOCITY CROSS RANGE, ST-124	0.1M/SEC/PULSE	05	F5-15 P1B1-05-08	450	NO
I7-802	VELOCITY RANGE, ST-124	0.1M/SEC/PULSE	05	F5-18 P1B1-05-09	1050	NO
I10-802	GUID CMD CHI X	10°/REV	05	F5-14M04 P1B1-05-10	14	YES
I11-802	GUID CMD CHI Z	10°/REV	05	F5-09 P1B1-07-01	60	YES
I13-802	GUID CMD CHI Y	10°/REV	05	F6-09 P1B1-07-02	60	YES

ORBITAL CHECKOUT PARAMETERS FOR IU-9
(EXTRACTED FROM IP&C LIST, IU-9)

MEASUREMENT NO./TYPE	NAME/OR COMPONENT	RANGE	% POS ERROR	T/M CHANNEL	RESP	FLT CALIB
GUIDANCE:						
I 20-802	DIG COMMAND RESET	ON-OFF		F6-03 P1B1-07-03	11	NO
VOLT FREQ CURRENT:						
M9-802	FREQ, INVERTER 1	400± .25CPS	05	F5-08 P1B1-07-04	45	NO
M13-802	COMMAND VOLTAGE	0-12V	05	P1B1-01-07	2.4	YES
M14-802	POWER TRANS BUS VOLT	0-28V	05	P1B1-01-01	2.4	YES
M16-802	D21 BUS VOLTAGE	24-32V	05	P1B1-01-02	2.4	YES
M17-802	D11 BUS VOLTAGE	24-32V	05	P1B1-01-03	2.4	YES
M18-802	D10 BATTERY CURRENT	0-150A	10	P1B1-01-04	2.4	YES
M19-802	D20 BATTERY CURRENT	0-150A	10	P1B1-01-05	2.4	YES
M35-802	FREQ, INVERTER 2	400± .25 CPS	05	F5-17M08 P1B1-05-03	45	YES
M36-802	MEASURING VOLTAGE	0-5V	05	F6-X-B19-01 P1B2-19-01	2.4 2.4	YES YES
M46-802	VOLTAGE INVERTER 1 ØAB	105-130VAC	05	F5-X-B19-02 P1B2-19-02	2.4 2.4	YES YES
M47-802	VOLTAGE INVERTER 1 ØBC	105-130 VAC	05	F6-X-B19-03 P1B2-19-03	2.4	YES
M48-802	VOLTAGE INVERTER 1 ØCA	105-130 VAC	05	F6-X-B19-04 P1B2-19-04	2.4	YES

ORBITAL CHECKOUT PARAMETERS FOR IU-9
(EXTRACTED FROM IP&C LIST, IU-9

MEASUREMENT NO./TYPE	NAME/OR COMPONENT	RANGE	% POS ERROR	T/M CHANNEL	RESP	FLT CALIB
VOLT FREQ CURRENT:						
M-53-802	RF PWR OUTPUT FS T/M	0-24W	05	F6-X-B04-07 P1B2-04-07	2.4	YES
M-55-802	RF PWR OUTPUT F6 T/M	0-24W	05	F6-X-B04-08 P1B2-04-08	2.4	YES
M57-802	RF PWR OUTPUT P1 T/M	0-20W	05	F6-X-B04-09 P1B2-04-09	2.4	YES
M59-802	RF PWR OUTPUT S3 T/M	0-24W	05	F6-X-B04-10 P1B2-04-10	2.4	YES
M61-802	VOLTAGE, 56 VDC	56-60V	05	P1B1-08-10	2.4	YES
M23-802	PWR OUTPUT AZUSA	0-2.4 VDC	05	P1B1-01-08	2.4	YES
M33-802	PWR OUTPUT RANGE MISTRAM	0-2.4 VDC	05	F6-X-B12-03 P1B2-12-03	2.4	YES
RF & TELEMETRY:						
J 12-802	RADAR ALTIMETER SIGNAL			P1B1-08-01 P1B2-08	DIG	NO
J 15-802	ALTIMETER RELIABILITY SIG	$\pm$ 0.5 to 5 VDC	05	F6-X-B01-03 P1B1-01-03	2.4	YES

APPENDIX 3

SIVB SWITCH SELECTOR OUTPUT
CHANNEL ASSIGNMENTS

REF: DAC Dwg. 1A69881 - Sequencer Assy. 404A3
(Numbers in parentheses are sheet numbers)

CHANNEL NO.		CHANNEL NO.	
1.	P.U. D.C. Supply & Oven ON (1)	26.	
2.	P.U. D.C. Supply & Oven OFF (1)	27.	Engine Start OFF (10)
3.	P.U. Fuel Boiloff Bias. CO ON (1)	28.	Aux. Hyd Pump ON (6)
4.	P.U. Fuel Boiloff Bias. CO OFF (1)	29.	Aux. Hyd Pump OFF (6)
5.	P.U. Activate ON (2)	30.	Aux. Hyd Pump Coast Mode ON (6)
6.	P.U. Activate OFF (2)	31.	Aux. Hyd Pump Coast Mode OFF (6)
7.	P.U. Inverter ON (2)	32.	1750 lb. Ullage ON (6)
8.	P.U. Inverter OFF (2)	33.	1750 lb. Ullage OFF (6)
9.	Engine Start ON (10)	34.	150 lb. Ullage ON (6)
10.	Engine Ready Bypass Com. (2)	35.	150 lb. Ullage OFF (6)
11.	Fuel Inj. Temp. Dtctr. Bypass Comm (2)	36.	Auto Vent Enable ON (7)
12.	Engine Cutoff ON (3)	37.	Auto Vent Enable OFF (7)
13.	Engine Cutoff OFF (3)	38.	Vent Open ON (7)
14.	Engine Control Heater ON (3)	39.	Fuel Tk. Repressure ON (7)
15.	Engine Control Heater OFF (3)	40.	SSB GR ON (8)
16.	Engine 200w Inst Htrs ON (3)	41.	SSB GR OFF (8)
17.	Engine 200w Inst Htrs OFF (3)	42.	Recorded Meas. GR ON (8)
18.	Engine 20w Inst Htrs ON (3)	43.	Recorded Meas. GR OFF (8)
19.	Engine 20w Inst Htrs OFF (3)	44.	Flight S.C.O. Group ON (8)
20.	Bleed Valves ON (5)	45.	Flight S.C.O. Group OFF (8)
21.	Bleed Valves OFF (5)	46.	ORBIT SCO Group ON (8)
22.	Ox. Chilldown Pump ON (5)	47.	ORBIT SCO Group OFF (8)
23.	Ox. Chilldown Pump OFF (5)	48.	ORBIT Xmtr Group ON (9)
24.	Pump Purge Valve ON (5)	49.	ORBIT Xmtr Group OFF (9)
25.	Pump Valve OFF (5)	50.	Flight Xmtr Group ON (9)

CHANNEL NO.		CHANNEL NO.	
51.	Flight Xmtr Group OFF (9)	86.	Range Safety I OFF (2)
52.	SSB Xmtr ON (9)	87.	Range Safety II ON (2)
53.	SSB Xmtr OFF (9)	88.	Charging Command Reset (19)
54.	Charge Ullage Ign. ON (1)	89.	
55.	Charge Ullage Jettison ON (1)	90.	
56.	Fire Ullage Ignition ON (11)	91.	
57.	Fire Ullage Jettison ON (11)	92.	
58.	Fuel Chilldown Pump ON (11)	93.	
59.	Fuel Chilldown Pump OFF	94.	
60.	In Flite Relays ON (16)	95.	
61.	In Flite Relays OFF (16)	96.	
62.	Special CAL. Relays ON (16)	97.	
63.	Special CAL. Relays OFF (16)	98.	
64.	Regular CAL Relays ON (16)	99.	
65.	Regular CAL Relays OFF (16)	100.	
66.	Record Relays ON (16)	101.	
67.	Record Relays OFF (16)	102.	
68.	Engine Burning 1 ON Com (17)	103.	
69.	Engine Burning 1 OFF Com (17)	104.	
70.	Engine Burning 2 ON Com (17)	105.	
71.	Engine Burning 2 OFF Com (17)	106.	
72.	Range Safety II OFF (3)	107.	
73.	Firing Command Reset (19)	108.	
74.	Engine Restart ON (10)	109.	
75.	Engine Restart OFF (10)	110.	
76.	Vent Open OFF (7)	111.	
77.	Vent Close ON (7)	112.	
78.	Vent Close OFF (7)	113.	
79.	Coast Period ON Com. (17)	114.	
80.	Coast Period OFF Com. (17)	115.	
81.	Fuel Tank Repressure OFF (7)	116.	
82.	ANTI Backflow Pilot Valve ON (11)	117.	
83.	ANTI Backflow Pilot Valve OFF (11)	118.	
84.		119.	
85.	Range Safety I ON (2)	120.	

APPENDIX 4

STAGE SYSTEMS TESTS GUIDELINES

Section 7.10.3 of SR-QUAL-64-13, "Space Vehicle Stage Analysis and Checkout Guidelines" is presented below as additional background material. This section establishes minimum requirements for the checkout of an assembled stage. A prerequisite to assembled stage checkout is that the stage assembly operations be completed and verified. The checkout guidelines and requirements included in this section are applicable to any launch vehicle stage.

7.10.3 STAGE SYSTEMS TESTS

7.10.3.1 Power Distribution

7.10.3.1.1 Objective

Power distribution encompasses all power utilized on the stage to operate electrical networks and related electrical and electromechanical components. The purpose of this test is to assure compatibility of stage and support equipment, correct assembly, satisfactory power distribtuion, correct electrical and mechanical function, satisfactory design, and readiness for succeeding tests. This will include verification of the following:

a. Proper mating of the GSE and stage.

b. Proper distribution of power throughout the stage and ground system and the electrical operation of electromechanical components.

c. The energization of all buses from proper power supplies and in the proper sequence.

d. The control and monitoring circuitry associated with the stage having the proper supply bus, design intent, installation, continuity, and system compatibility.

e. Proper impedance on all buses.

f. Correct distribution of power so that no "shorts" or "sneak circuits" exist in the system.

7.10.3.1.2 Requirements

a. Verify GSE-stage connections according to interconnecting diagram.

b. Ascertain that all power connections have been made and that the resistances of all supply buses are correct.

c. Verify that the power is properly applied in the proper sequence to all circuits, electrical networks, electromechanical and electrical components, and that the load on all buses is correct.

d. Ascertain that all electrical controls operate properly to control pneumatic supplies, pressurization and venting valves, propellant fill and drain valves, prevalves, air bearing valves, and all other system valves in preparation for subsequent tests.

e. Only the basic networks shall be used; i.e., items that are part of other subsystems shall be disconnected. This is to assure that components are not energized before being checked out.

f. The independence of stage buses shall be confirmed.

7.10.3.2 Airborne DDAS Calibration

7.10.3.2.1 Objectives

This calibration is to assure the airborne DDAS is accurately calibrated for its use as a checkout tool prior to the commencement of testing.

7.10.3.2.2 Requirements

a. Parameters of the airborne DDAS are to be measured as outputs of the DDAS ground station.

b. The signal cables containing the analog measurements shall be disconnected from each commutator.

c. A cable harness from a 0- to 5-volt precision power supply shall be connected to the input of each commutator in sequence so that a known voltage can be applied to all inputs of an individual commutator simultaneously.

7.10.3.3 Pressure and Functional Tests

7.10.3.3.1 General Objectives

The objective of performing pressure and functional tests on the mechanical systems of the stage is to assure the integrity and functional capability of the mechanical systems in the stage. The checkout shall not be a matter of merely making visual or functional type inspections in conformance with the design specifications, but rather it is an operational test.

7.10.3.3.2 General Requirements

Methods outlined in this paragraph shall be incorporated in the tests:

a. All connections that are disconnected in order to perform a test must be retested for leakage.

b. Leak test solution shall not be used on braiding of flexible lines, bellow, pneumatic bleed ports, or flared surfaces of AN fittings and tubings.

c. All leak detection solution shall be completely removed from all fittings, lines, components, and assemblies, with an approved solvent, after testing. Care shall be exercised to prevent foreign matter from entering vents, bleed, or pilot openings.

d. All protective covers removed from the stage and test equipment shall be immediately replaced upon completion of test.

e. At no time shall any line connections or fittings, flanges, or fixtures be disconnected while a system is pressurized.

f. All systems being tested shall be pressurized slowly to, and shall not exceed the specified pressures of the system.

g. If any audible leakage is detected within the specified pressure range, it shall be marked and recorded for correction.

h. All test lines, connections, fittings, and fixtures shall be tested and free of external leakage prior to beginning any pressure "drop-off" test.

i. Where it is not feasible to measure allowable component leakages by using downstream flowmeters or upstream flowmeters, the system shall be pressurized to a known volume and pressure/temperature will be monitored, and a decay or drop-off test shall then be performed.

j. All high-pressure tests shall be conducted utilizing incremental pressure steps. Five-minute intervals are recommended between pressure steps.

k. Audible leak detectors shall be utilized during high-pressure tests to inform the test conductor of system audible leaks.

l. Structural system pressurization tests shall be conducted at test pressure, with the test cell evacuated of all personnel. Then systems will be checked at safe pressure with personnel in test cell to check for leaks using approved leak detection solution. Systems shall be vented and a trace gas leak check shall be conducted.

m. Any faulty pressurized system must be depressurized before repairs are attempted.

n. Tracer gas utilized for leak detection shall be handled in such a manner as to avoid contaminating areas where future leak tests will be conducted. Systems tested with tracer gas shall not indiscriminately be vented into these areas.

o. In the event any system is "opened" after a leakage test has been performed, the system shall be retested for leakage.

p. Using leak detection solution and tracer gas, check all fittings, tubing, connections, and flanges relevant to the stage systems. No external leakage is allowed.

q. Flowmeter tests shall be utilized to check all valve seats, seals, etc.

r. Care shall be exercised to insure that the pressure range of pressure transducers in any system shall not be exceeded during system pressurization tests.

s. All pressure gages and pressure transducers must be calibrated within 30 days before use in testing a stage.

Records of all system actuation timing, pressure levels, etc. shall be obtained and evaluated. Testing time is minimized by performing instrument calibration tests in conjunction with instrumentation checkout personnel.

7.10.3.3.3 AC Heaters

7.10.3.3.3.1 Objectives

Verify proper heater operation.

7.10.3.3.3.2 Requirements

a. Attach temperature transducers as close to the thermostat as possible without direct contact being established with the heater elements.

b. Verify that proper voltage is applied to assure validity of current readings received.

c. All heater units must be cycled three times.

d. Compare, display, and print out amperage drawn by each heater and temperature limits of the controlling thermostat for three cycles of each component.

7.10.3.3.4 Pressure Switches Test

7.10.3.3.4.1 Objectives

The objectives of this test are to verify pressure switch operation, to leak test at system pressure, check for internal and external leakage, verify actuation and de-actuating pressure settings, and make and break repeatability of the switches.

7.10.3.3.4.2 Requirements

a. All pressurization cycles are to be performed three times in order to insure consistent results.

b. All systems shall be pressurized at a reasonable rate to maintain adequate control. (High-pressure systems should be limited to a maximum pressurization rate of one percent of maximum system pressure per minute near upper limits.)

c. All pressurization system connections shall be leak checked at an intermediate level of operation.

d. Go to system pressure slowly and vent to zero slowly for each cycle.

e. All systems shall be checked for leaks on first pressurization cycle. Actuation and de-actuation pressures shall be determined on the first and subsequent cycles. All switches shall be cycled three times by going to system pressure and then venting to zero for each cycle.

f. The actuations and de-actuations shall be observed and recorded during increasing pressure and decreasing pressure, and they shall be checked to determine if they are within specified tolerances.

g. All connections shall be leak checked.

7.10.3.3.5 Control Pressure System

7.10.3.3.5.1 Objectives

The objectives of this test are to check system integrity, external and internal leakage of the system and components, minimum pressure required for component operation, and relief settings of high-pressure regulator and system relief valves. In addition, check response timing and repeatability of component operation, proof test system and components at normal system operating pressure, and check and assure that the GN_2 control system purges are within specification.

7.10.3.3.5.2 Requirements

a. Audible leak check of the high-pressure system shall be performed at a reduced, safe pressure level.

b. High-pressure systems shall be pressurized using suitable increments. The maximum pressure level shall be maintained for five minutes.

c. All high-pressure connections, components, bottle fill, and vent valves shall be leak checked at a man-safe pressure.

d. All system valves shall be checked for seal leaks.

e. All system valves shall be checked to ascertain that they will actuate to full-open position.

f. All relief valves shall be checked to determine if cracking and seating pressures are within specification.

g. All prevalves, relief valves, replenishing valves, fill and drain valves, and vent valves shall be time checked.

h. All valves shall be cycled three times and the three results compared to insure normal system operations.

7.10.3.3.6 Gas Generator Oxidizer and Fuel Control Valve Assemblies

7.10.3.3.6.1 Objectives

The objectives of this test are to determine external leakage of components and connections, internal leakage of poppet seats, pressure required to open poppets, and the repeatability of operation of the system components.

7.10.3.3.6.2 Requirements

a. The cracking pressure of all system valves shall be determined.

b. All system connections shall be checked using audible, suitable leak detection solution, and pressure differential methods.

c. Internal leakage of all valves shall be checked.

d. The oxidizer and fuel valves shall be cycled three times, and the results obtained must be consistent.

e. The repeatability of all system components must be ascertained.

f. All components are operated to determine proper actuation and de-actuation pressure levels.

7.10.3.3.7 Gas Generator, Gas Turbine, Turbine Exhaust and Turbopump Gearcase Test

7.10.3.3.7.1 Objectives

The objectives of this test are to check the gas generator system for external leakage, turbine seal leakage, turbopump torque, audible noise during turbopump torque test, and cracking pressure of lube oil drain check valve and its repeatability.

7.10.3.3.7.2 Requirements

a. All connections and fittings shall be checked for leaks using a suitable leak detection solution. No external leakage shall be allowed.

b. Turbine seal leakage shall be checked with a suitable flowmeter.

c. All bellows, flanges, and welds in these systems shall be leak checked with a suitable tracer gas. No leakage shall be allowed.

d. Turbopump gearcase fittings, connections, measurements, flanges, and tubing shall be checked with a suitable tracer gas. No external leakage shall be allowed.

e. Turbopump gearcase pressurization check valves shall be checked for reverse leakage.

7.10.3.3.8 Engine Control System Tests

7.10.3.3.8.1 Objectives

The objectives of this test are to check for external and internal leaks, for minimum pressure required for main oxidizer valve and main fuel valve operation, for "no actuation" and "actuation" of ignitor monitor valve, position potentiometer of main oxidizer valve and main fuel valve for closed position, open position and total valve position, functional operation of sequence valve, and system integrity. Also a check of response, timing, and repeatability of main oxidizer valve, main fuel valve, ignitor monitor valve, and proof test system for components at normal operating pressures of the system is conducted.

7.10.3.3.8.2 Requirements

a. All connections, fittings, and housings must be leak checked with a suitable leak detection solution. No external leakage will be allowed.

b. Internal leak check around O-rings and other seals shall be conducted utilizing flowmeters.

c. All valves shall be checked for cracking and seating pressures and must comply with specifications.

d. All system components shall be checked to assure they are operative and capable of obtaining full-open position.

e. All test fixtures installed in a system must be red-tagged with a tag of sufficient size to insure detection.

f. Oxidizer and fuel valves shall be checked for smooth operation (no binding or sticking allowed).

7.10.3.3.9 Oxidizer Pressurization System

7.10.3.3.9.1 Objectives

The objectives of this test are to check for binding and bending of oxidizer lines and expansion joints, for external leakage, for seal leakages of valves, for system integrity, and proper functioning of the flow control valve. The system shall be pressurized to proof pressure.

7.10.3.3.9.2 Requirements

a. A leak check of all lines, fittings, and connections shall be conducted under a suitable test pressure using leak detector solution or tracer gas as applicable. The system shall be pressurized and checked for pressure decay and reverse leakage of valve seats. The oxidizer pressurization system shall be checked at proof pressure for functional operation. GOX flow control devices shall be functionally tested within the system by simulating tank pressures and other controlling parameters while monitoring valve responses.

b. All leak detection solution shall be removed using a suitable solvent. All control devices are functionally tested.

7.10.3.3.10 Engine Purge System

7.10.3.3.10.1 Objectives

The objectives of this test are to check for external leakage, system integrity, proof test at normal system operating pressures, component operation, and system flow rates.

7.10.3.3.10.2 Requirements.

a. System lines and storage equipment shall be pressure checked at operating pressure and a flow measurement conducted.

b. A leak check of all lines, fittings, and connections shall be conducted under pressure, utilizing a suitable leak detection solution. No external leakage is allowable.

c. Internal leakage of the system components shall be measured with a flowmeter.

7.10.3.3.11 Propellant Utilization

7.10.3.3.11.1 Objectives

The objectives of this test are to check for external leakage, check regulators for pressure and flow regulation, and assure system integrity.

7.10.3.3.11.2 Requirements

a. All regulators, check valves, and bypass valves connections and fittings shall be leak checked at a safe pressure level using a suitable leak detection solution. No external leakage is allowable.

b. All systems shall be pressurized to operating pressure to perform a pressure drop-off test. The system should contain the pressure for a specified period.

c. A functional test of all system components shall be made to verify operational capabilities.

7.10.3.3.12 Oxidizer Tank and Combustion Chamber Test

7.10.3.3.12.1 Objectives

The objectives of this test are to check for external leakage, internal leakage of vents and valves, system integrity, binding in all expansion joints and bellows on interconnects and feed lines, and functional operation of all components.

7.10.3.3.12.2 Requirements

a. Leak checks shall be conducted using audible leak procedures, tracer gas, and leak detection solution to check all fittings, connections, and flanges.

b. Internal leakage checks of all valve seats shall be conducted utilizing flowmeters.

c. Oxidizer tank shall be pressurized in increments to test pressure. A suitable time interval shall be allowed between increments. System shall be maintained at proof pressure for five minutes. Pressure shall be reduced to safe level before personnel enter the test area.

d. Oxidizer turbopump shall be checked for oxidizer seal leakage and torque required to rotate each pump.

e. All combustion chamber purge lines shall be leak checked using suitable leak detection solution.

f. All combustion chambers shall be leak checked.

g. A functional check of all component operation shall be conducted.

7.10.3.3.13 High-Pressure Spheres and Fuel Tanks

7.10.3.3.13.1 Objectives

The objectives of this test are to determine external leakage, internal leakage of components, functional operation of components, binding in all expansion joints and bellows, and system integrity.

7.10.3.3.13.2 Requirements

a. Proof pressure test shall be conducted on the high-pressure systems and the pressure drop-off observed.

b. External leak checks using audible leak detection procedures shall be conducted at safe pressure levels.

c. All fittings and connections shall be leak checked at safe pressure level utilizing suitable leak detection solution and tracer gases.

d. Internal leak checks of all valves shall be conducted utilizing flowmeters.

e. Audible leak checks shall be made of the fuel tanks.

f. Tracer gas leak checks of fuel tanks shall be conducted after audible leak checks. A suitable tracer gas detector shall be utilized to check for leakage.

g. Fuel turbopump seal leakage shall be checked.

h. A functional check of all system components shall be conducted.

i. The high-pressure spheres and fuel tanks shall be pressurized to a safe level to check system integrity, using a suitable gas detector.

7.10.3.3.14 Hydraulic Systems

7.10.3.3.14.1 Objectives

The objectives of this test are to check hydraulic systems for proper response, and system integrity. Each engine is gimballed to verify structural clearance and proper travel.

7.10.3.3.14.2 Requirements

a. All personnel must be cleared from vehicle tail area before hydraulic systems are actuated.

b. Visual checks shall be conducted to assure clearance with respect to surrounding stage equipment.

c. Visual checks for twisting, buckling, or stretching of flexible hoses or wiring.

d. Visual checks for evidence of leakage.

e. Check of smooth operations of system.

f. A check shall be conducted to assure ability to fully extend and retract both the pitch and yaw actuators simultaneously (corner clearance check).

g. Check all gimbal and expansion joints to assure proper operation.

h. All actuator locks must be installed at completion of tests.

7.10.3.3.15 Instrument Canister and Cooling System

7.10.3.3.15.1 Objectives

The objectives of this test are to check structural integrity, external leakage, components for internal leakage, and operation of cooling system components.

7.10.3.3.15.2 Requirements

a. Audible and visual leak checks shall be conducted over a suitable pressure range.

b. A minimum number of personnel shall be allowed in test cell to detect leaks while system is pressurized.

c. Instrument canisters shall be pressurized slowly utilizing increments of pressure. Sufficient holding times shall be allowed between pressure steps.

d. After maximum pressure level has been obtained a suitable drop-off test shall be conducted.

e. All system connections and fittings shall be leak checked with a suitable leak detection solution and tracer gas.

f. Verify the proper function of all cooling system components.

7.10.3.4 General Network and Malfunction Tests

7.10.3.4.1 Objectives

a. Verify over-all design, function, and compatibility of the various cutoff sequences.

b. Verify proper operation and compatibility of the power transfer circuits, launch sequencer, and flight sequencer.

7.10.3.4.2 Requirements

a. Exercise all circuits required to obtain firing command.

b. Initiate power transfer from ground power to stage power and return.

c. Exercise the stage flight sequencer to ascertain its proper operation.

d. Exercise all methods of cutoff. This may entail giving firing command and introducing malfunctions to ascertain if the malfunctions can be detected and the proper action taken.

e. After each cutoff, recycle the system to prelaunch condition to prove that after each, the system can be recycled to a safe condition.

f. Exercise all elements of the CDR system. Verify retro rockets, ullage rockets, and separation systems commands properly received.

g. Conduct special tests, if necessary, to verify each redundant circuit.

h. The initial part of this test should consist of verifying the network circuitry associated with vehicle engine cutoff in the following areas:

   (1) Command-destruct system with command receivers.

   (2) Flight sequencer.

   (3) Propellant depletion circuits.

   (4) Low thrust cutoff circuits.

i. The EBW subsystem in the retro rocket and destruct systems shall be verified.

j. The sequence of switching necessary for preparations completion shall be checked, followed by a check of various premature cutoff sequences by introducing malfunctions into the automatic sequence after firing command. A normal firing sequence is accomplished with umbilical retraction occurring automatically at the appropriate time. The umbilical retraction is simulated during the prestatic tests. The one-shot safety relays shall be test fired. Cutoff is given after liftoff by the ground command transmitter via the stage command receivers. Since no guidance and control equipment is connected during this test, position indicators are simulated.

7.10.3.5 Measuring System

7.10.3.5.1 Objectives

a. To verify the calibration of all transducers located on the stage where practical.

b. To verify the calibration of the signal conditioners associated with the transducers.

c. To assure subsystem conformance to proper channel assignments as determined by applicable documentation.

7.10.3.5.2 Requirements

a. The parameters to be checked are dc voltages, ac voltages, and frequencies, representing measurements of the following:

(1) Propulsion.

(2) Expulsion.

(3) Temperature.

(4) Pressure.

(5) Strain.

(6) Vibration.

(7) Flight Mechanics.

(8) Steering Control.

(9) Stabilized Platform.

(10) Guidance.

(11) RF and Telemetering.

(12) Signals.

(13) Voltages

(14) Currents.

(15) Frequency, etc.

b. The outputs of the measurements and signal conditioners shall be returned to the checkout computer via the DDAS and/or the telemeter systems where they shall be compared against predicted values.

c. Those measurements originating from the operation of some system or component shall be monitored as the related system or component is operated through discrete steps.

d. Those measurements originating from the stage environment shall be monitored as they are stimulated by the proper environmental change. With some measurements, this shall consist of a gross stimuli applied just enough to obtain a significant output of the gage, with others, this shall consist of applying stimuli by means of special built-in aids, while others shall require the substitution or addition of some special networks just for checkout.

e. The rule shall be to actually stimulate or operate the system for every flight measurement. Simulation shall only be accepted when degradation of the stage would occur or the probe is inaccessible.

f. The computer program shall provide for a printout of all data, both acquired and stored, in various groupings to be utilized by the test conductor during checkout.

7.10.3.6 Telemetry Systems

7.10.3.6.1 Objectives

Determine that the telemetry system operates in compliance with applicable specifications while installed in and controlled via stage networks.

7.10.3.6.2 Requirements

a. The following prerequisites should be completed.

(1) Completion of functional checkout (including timing and calibration) of all TLM system components in a bench test setup.

(2) Tuning of TLM antenna systems.

b. The following parameters should be checked.

(1) Transmitter powerout and reflected power.

(2) RF amplifier power output and reflected power.

(3) All voltages on main and RF power amplifier chassis.

(4) Calibration step amplitude.

(5) Commutator rate and format.

(6) Transmitter frequency and deviation.

(7) Spurious signals of each transmitter.

(8) Spurious signals of multicoupled transmitters.

(9) Subcarrier oscillator frequency, deviation, stability, linearity, and pre-emphasis.

(10) Multicoupler efficiency.

c. All parameters, as a minimum, listed above will be measured (either manually or automatically) while the TLM system is operating in the stage network in as near a flight configuration as possible. These measurements will be compared with measurements obtained previously in the functional bench check to determine trends and for compliance with applicable specifications.

d. Calibration of subcarrier oscillators will be checked and adjusted as necessary.

7.10.3.7 <u>RF Systems</u>

7.10.3.7.1 Objectives

a. Verify altitude measuring capability.

b. Verify proper antenna tuning and installation.

c. Validate proper response of safety RF systems.

d. Verify that all tracking devices have the proper frequency.

7.10.3.7.2 Requirements

a. Interrogate the radar with five known altitude simulation delays.

b. Transmit destruct and non-destruct commands and monitor all responses. AGC characteristics shall be determined at five signal input levels.

c. Make VSWR and electrical phasing checks of the coaxial cables.

d. Stimulate antennas with center frequency and monitor for proper null.

e. Energize RF transponders and compare measured frequency and power output with bench test results.

f. The installation of all antennas shall be visually inspected for proper installation, sufficient electrical continuity, etc. Satisfactory antenna tuning shall be verified using the stage skin as a ground plane. Electrical phasing of all interconnecting coaxial cables shall be verified by actual test and proper cable installation shall be determined by visual inspection. The results of antenna tuning and cable phasing bench tests shall be used in determining satisfactory operation after stage installation.

g. Performance evaluation of the stage RF systems is variable as a function of the type of system being evaluated. All RF system evaluation should be performed through an open-loop type coupling since this more nearly approximates flight conditions. RF receivers shall be interrogated from an appropriate ground station. This interrogation shall include the transmittal of all command signals to which the receiver is to respond, and the careful evaluation of the receiver responses. Triggering of all stage RF transmitters is initiated from the appropriate ground station and the resulting transmitter response carefully evaluated. In general, the stage RF systems evaluation is not an absolute measurement of parameters previously measured during bench functional tests, but is an operational performance test. For example, absolute receiver sensitivity, bandwidth, etc., measurements are not attempted. Additionally, absolute transmitter power output levels are not measured during this evaluation, although frequency, pulse repetition rates, etc., are a part of the system evaluation.

7.10.3.8 Thrust Vector Control System

7.10.3.8.1 Engine Gimballing System

7.10.3.8.1.1 Objectives

a. Verify the linearity of each actuator position potentiometer.

b. Verify proper polarity of each actuator.

c. Verify that there is no interaction between actuator operations.

d. Verify engine gimballing system instrumentation.

7.10.3.8.1.2 Requirements

a. Apply a stimulus to each actuator and record the actuator position potentiometer output - compare with calculated values, and the actual position of the actuator.

b. Apply stimuli to all engines simultaneously and observe engines and engine deflection measurements for smoothness of operation.

c. Record and evaluate engine instrumentation such as hydraulic temperature and pressure, etc.

7.10.3.8.2 Rate Gyro Assembly Tests

7.10.3.8.2.1 Objectives

The objectives of the tests of the rate gyro assembly are to verify proper functioning of the rate gyros and their associated electrical support equipment.

7.10.3.8.2.2 Requirements

a. Verify rate gyro up to speed indication.

b. Apply stimuli to torquer circuit and measure torquer current, command output and telemeter output, for proper polarity and amplitude.

c. With the stage control system power on, the telemeter recording equipment operating, the rate gyro power on, and the package loose from its mounting bracket, the rate gyro package shall be slowly turned, about one sensitive axis at a time so that the correct polarity and channel identification can be made of the output signals from each sensing element in the package.

d. After the identification and polarity test is performed, the package will be secured to its mounting bracket before continuing with the torque test. Through the appropriate test station or stage interface test set, signals are applied to the torque coils of each rate gyro in turn and the output is checked against specifications in the checkout computer. While the above tests are being performed, observations will be made at the indicating meters on the appropriate test console and the telemeter recordings are observed for any malfunction.

7.10.3.8.3 Control Accelerometer Tests

7.10.3.8.3.1 Objectives

The objectives of the tests of the control accelerometers are to verify the proper functioning of the pitch and yaw control accelerometers and the associated electrical support equipment.

7.10.3.8.3.2 Requirements

a. Apply stimuli to torquer circuit and measure torquer current, command output, and telemeter output for proper polarity and amplitude.

b. With the stage control system power on and the control accelerometers on, signals via an appropriate test station and the stage interface set shall be applied to each of the control accelerometers. These input signals shall be monitored at the stage interface set or at an appropriate test station.

c. The correct functioning of the control accelerometers shall be monitored by observing the control accelerometer output signal level via the stage interface set panel meters or on an oscillograph recorder. These tests shall be applied in turn to the pitch and yaw control accelerometers.

7.10.3.8.4 Auxiliary Control System Assemblies

7.10.3.8.4.1 Objectives

The objectives of the auxiliary control system assemblies (i.e., reaction control devices) checkout tests are to verify that the initiation, actuation, duration, and decay of the flow through each reaction control device meets the designated performance specifications.

7.10.3.8.4.2 Requirements

a. Stimulate the auxiliary control system and measure the duration, decay, and deadband characteristics and compare with specified values.

b. With the stage control system power on, stimuli will be applied to the auxiliary control system which pulses the reaction control device on and allows flow through the reaction control jets.

c. Measurements of the actuation, duration, decay, and deadband characteristics of the device will be compared with specified values.

7.10.3.9 Steering Over-All Test

7.10.3.9.1 Objectives

The objectives of the steering over-all test are as follows:

a. To prove the compatibility of the thrust vector control system with the stage networks.

b. To eject the umbilicals and prove the stage can function without the power and control cables connected to the GSE.

7.10.3.9.2 Requirements

a. Initially, the stage systems and ground support equipment shall be brought to a state of readiness in order to accept the automatic sequence initiated by the firing command. All indicators shall be monitored for proper status. Examples of the more important indications that will be displayed are power monitoring, fuel dispersion safe, ignition safe, all plugs connected, fuel vents closed, all supports supporting, all manual locks in, CDR signals blocked, stage cutoff safe, safety relays installed, and arming units safe.

b. The RF and telemetry systems are not active during this test.

c. The measuring system is active to the extent of monitoring the hydraulic and gimballing system.

d. Apply power to the stage and place the system in a ready-to-fire status.

e. Simulate error commands to the engine gimballing system.

f. Initiate firing command and allow the sequence to proceed normally with liftoff given by ejecting the umbilicals.

g. Continue the flight sequence until all timing and flight operations have ceased.

7.10.3.10 RF Compatibility Test

7.10.3.10.1 Objectives

a. To determine if any interaction exists between RF systems.

b. To determine if the RF systems are adversely affected by the operation of other electrical and electronic equipment.

c. To determine if other electrical and electronic equipment is adversely affected by the operation of the RF systems.

7.10.3.10.2 Requirements

a. Bring all stage systems to an operating condition and verify normal operation.

b. In a prescribed sequence, energize all of the stage RF systems individually.

c. Monitor the AGC and frequency measurements as the various systems are operated.

d. Satisfactory performance of both the RF system and the associated stage system shall be verified. This procedure shall be continued as each RF system, including telemetry, is energized and as all RF systems are collectively operated.

7.10.3.11 Electromagnetic Compatibility (EMC) Test

7.10.3.11.1 Objectives

a. To determine if all vehicle and ground support equipment electrical, electronic, and electromechanical systems and subsystems will operate, both individually and simultaneously, without degraded performance due to EMC.

b. To determine that the vehicle structure provides the low dc resistance and ac impedance necessary for a satisfactory vehicle ground plane.

7.10.3.11.2 Requirements

a. Monitor all frequency bands where frequency interference is most suspected. The results of the stage frequency allocation analysis will be used to determine the suspected frequencies.

b. Monitor critical and susceptible stage circuits during subsystem and system tests.

c. Analyze all data obtained versus the electromagnetic interference and susceptibility test data taken during bench testing.

d. The EMC Test shall be performed concurrent with the normal vehicle stage checkout and shall require a minimum of allocated time in the over-all checkout schedule.

e. The test will consist of monitoring the response, output, and/or performance during, first, individual, and then simultaneous, functioning of critical stage and ground support equipment systems, and subsystems.

f. Criticality of subsystems and systems shall be determined by susceptibility characteristics and function performed during checkout and/or flight.

g. Any vehicle or ground support equipment systems and subsystems exhibiting extreme susceptibility to electromagnetic signals shall be monitored during the EMC Test. Additionally, any ground support equipment or vehicle systems and subsystems necessary for a valid checkout or flight mission accomplishment shall be monitored during the EMC Test.

h. The final EMC Tests shall be performed on complete vehicle stages; abbreviated EMC Test will be performed on subsequent identical stages after sufficient confidence has been gained through EMC testing. If consecutive vehicle stages differ significantly, a comprehensive EMC Test shall be performed on each stage.

i. EMC Tests will define radiated and conducted electromagnetic characteristics and dc resistance measurements to determine the adequacy of the vehicle ground plane. The signal inputs to the Command Destruct System will be monitored around the Receiver fundamental and image frequencies.

j. Transient, continuous wave, and broadband interference signal monitoring shall be included in any comprehensive vehicle stage conducted EMC Test.

k. EMC conducted test data shall be thorough enough to not only provide a definition of an individual stage electromagnetic characteristic, but shall also provide the characteristics relative to interfacing conductors between various vehicle stages.

l. DC resistance measurements shall be made between all major segments of the vehicle structure. These measurements shall be made when no power is applied to the vehicle stage. Particular attention shall be given to the measurements between instrumentation systems, canisters, etc., and the stage tanks and spider beams. The method by which the vehicle ground system is established shall be visually inspected to assure a satisfactory ac as well as dc grounding scheme.

7.10.3.12 Instrumentation Compatibility Test

7.10.3.12.1 Objective

Verify the over-all calibration polarity and operation of the flight instrumentation system, by making a complete end-to-end simultaneous check of each measurement channel.

7.10.3.12.2 Requirements

a. The parameters to be measured and recorded are the outputs of the DDAS and telemeter systems.

   (1) Built-in calibrations such as RACS and telemeter calibrations shall be checked at all points of operation.

   (2) Pressure transducers with calibration ports shall be checked at three different pressure levels.

   (3) Those measurements originating as functions of GSE or stage networks are to be monitored as these systems are cycled through significant operations.

b. The telemetry and DDAS systems shall be active and operating with their ground stations.

c. Each measurement channel shall be active and recorded by the computer and on magnetic tape through the telemeter ground station as it is stimulated.

d. The output of each telemetry channel shall be compared with the corresponding DDAS channel and a printout of this comparison made by the computer.

e. Those channels not returned to the computer by DDAS shall be compared to the calibration curve verified during the measuring system test.

f. A complete set of oscillograph records of the telemetry systems operation during this test shall be made from the magnetic tape and made immediately available for a quick-look evaluation.

7.10.3.13 Simulated Flight Test

7.10.3.13.1 General

This test consists of both the simulated plug drop and the plug drop tests. The simulated plug drop test is run during manufacturing and post-static operations, whereas the plug drop test is performed only during post-static operations.

7.10.3.13.2 Simulated Plug Drop Test

7.10.3.13.2.1 Objectives

a. To verify all of the stage systems can be brought to a state of readiness for firing command.

b. To verify that power transfer can be accomplished without any adverse effects on any of the systems.

c. To verify that exercising the thrust vector control system does not adversely effect any of the systems.

d. To verify that the stage can be programmed through the firing sequence, simulated liftoff, and that all inflight functions operate properly.

7.10.3.13.2.2 Requirements

a. All of the systems will be active. The simulated plug drop will be conducted by setting stage systems and appropriate stage substitutes.

b. All functions necessary to obtain "launch preparations complete," a firing sequence, and simulated flight will be performed.

c. At simulated liftoff the umbilicals are not ejected. This is necessary to verify that all of the functions, where the response is not telemetered but is hard-wired to the GSE, occur at the proper time and/or in proper sequence, and to provide additional instrumentation.

d. Perform a power transfer test and gimbal the engines prior to firing command.

e. Thrust Vector Control system responses are investigated on such problems as stability, actuator-bounce frequency response, transfer functions, etc.

f. Check for functioning of command destruct system prior to firing command.

g. Before and after any function, ascertain that the stage responses are proper. Also that they remain proper throughout the test.

h. Those functions which cannot be performed for safety reasons, etc., are simulated.

i. During the simulated plug drop test the stage will be programmed through the same sequence as the steering over-all test with the following exceptions: retraction of umbilicals will be simulated; engine cutoff is initiated by simulation; all stage flight systems are made active. Since the umbilicals are not ejected during this test, the sequence records of networks operation after liftoff are more inclusive than those of other composite tests. The data from this test will reveal any interaction between subsystems prior to the plug drop test. Since all measurements are recorded, the accuracy of transmitted and telemetered information can be verified.

7.10.3.13.3 Plug Drop (Simulated Flight Test)

7.10.3.13.3.1 Objectives

The objectives of this test include the ones of the previous test plus the following:

a. To verify in detail that the measuring system operates properly and within the proper tolerances.

b. To verify that all of the systems will function properly after the umbilicals are disconnected.

c. Verify that malfunction cutoff will shut down stage.

7.10.3.13.3.2 Requirements

a. Verify, prior to firing command, that the measuring system is operating within tolerance.

b. Remove all subsystem monitoring equipment that has been used for the lower level testing.

c. The countdown should be as close to an actual launch countdown as possible.

d. During the plug drop test, the functions performed should be identical to those of the simulated plug drop test except those which are changed because the umbilicals are actually ejected.

e. Engine cutoff will be given: by simulating fuel depletion, by simulating thrust decay and the destruct signal from command receivers upon termination of the flight sequence. The test results and stimuli will be monitored by use of meters, recorders, consoles, etc., at points of interest.

f. The simulated flight sequence shall be recorded via the telemetry on magnetic tape and oscillograph records of the telemetry channels shall be made and presented immediately for a quick-look evaluation of the test by the procuring agency and the test coordinator.